WATER SUPPLY STUDY PREPARED FOR THE CITY OF GRANDE PRAIRIE ALBERTA

by: J.F. Jones

1961-8

DRAFT

~~July 1960~~ ~~1960~~ 2

GRANDE PRAIRIE WATER SUPPLY

The following outline of the sequence of events concerning the Grande Prairie water supply problem is based on files of correspondence, annual reports and manuscripts of the Research Council, and on the December 1961 report of Stanley, Grimble and Roblin Limited to the City of Grande Prairie.

Stanley, Grimble and Roblin Limited were retained by the City of Grande Prairie in March, 1957 and again in August, 1959 to prepare a report on the water resources available in the vicinity of the City. An interim report was submitted in November, 1957, and a more comprehensive report in December, 1961.

The Research Council's groundwater geologist for the Peace River region, Mr. J. F. Jones, obtained leave of absence to return to the University of Western Ontario from September, 1959, to May, 1960. In October 1959, Dr. D. Stanley visited the Research Council, and discussed the Grande Prairie survey with Mr. R. N. Farvolden, ~~[illegible]~~ then head of the Groundwater Division. In a memorandum to Jones (Nov. 3, 1959) Farvolden noted that Stanley did not consider a pipeline to the Wapiti River would be economic unless groundwater could be developed at the river. Farvolden states: "I suggested

(1) Explore the gravel bars along the present river channel
(2) Test drill across the wide valley between Grande Prairie and uplands to the west of the city, along the highway (possible buried gravels)
(3) Check possibilities of artificial recharge into terrace gravels."

Preliminary investigations were carried out by Stanley, Grimble and Roblin, Ltd., on the gravel deposits along the Wapiti River in 1959. Late in that year or early in 1960, Dr. C. P. Gravenor met with Dr. D. Stanley and with City of Grande Prairie representatives and was asked whether Council could aid the Grande Prairie investigations. (Council was at this time considering a contractual arrangement by which Council would carry out a test-drilling program for municipal groundwater supplies if the program had research value and where a smaller community would run a considerable financial risk undertaking such a program on its own.) Dr. Gravenor wrote to Dr. Stanley (February 9, 1960) informing him that the Grande Prairie situation had been discussed with Groundwater Division staff and that it was concluded that the proposal did not fall within the scope of Council's projected contractual arrangement with municipalities. The reasons for turning down the Grande Prairie request were stated: (1) "In the case of Grande Prairie the problem is quite straightforward and does not form part of our research program in the foreseeable future", and (2) "One of the purposes of the aid program is to remove the burden of risk from a smaller community where the supply is doubtful. In the case of Grande Prairie the

S.G.R

information you now have on the water-saturated gravel would suggest to us that the risk is not great in obtaining a suitable supply."

Dr. Gravenor, however, offered Council's services in recommending a drilling program, in carrying out pump tests and in interpreting the results.

By early February, 1960 then, both Council and Stanley, Grimble and Roblin Ltd., were aware that water-saturated gravels existed in considerable thickness adjacent to the Wapiti River south of Grande Prairie. (Dr. N. H. Grace's letter to Hon. A. R. Patrick, Feb. 10, 1960, with a copy of Dr. Gravenor's letter of Feb. 9 attached, states that "there is quite a bit of information on water-saturated gravel in the Grande Prairie zone." However, as to what this information consisted of there is no record on file.) Council's conclusion that the problem was simple could have been based only on comparison with analogous geological situations in the United States from which water supplies had been obtained, as no drilling or testing of the Wapiti River gravels is known to have been carried out by February, 1960.

Mr. J. F. Jones returned to Council in May, 1960, and, because of an interest aroused by the Grande Prairie situation, undertook a test-drilling program to evaluate the groundwater potential of river-terrace gravels along the Wapiti River at Wembley and Grande Prairie and along the Smoky River at Watino. That part of this program of specific interest to the City of Grande Prairie was the drilling, in August, 1960, of 4 wells on the terrace south of the Wapiti River and east of the Grovedale Bridge, and the pump test carried out at this site. The annual report of the Groundwater Division compiled in September, 1960, states: "Although pumping tests have not been completely interpreted, preliminary results indicate that large quantities of water are available at Grande Prairie, Wembley and Watino." Jones' manuscript, completed December, 1963, states similarly: " it was apparent that ..... large amounts of water might be obtained by induced infiltration ....."

These conclusions were transmitted to Stanley, Grimble and Roblin Limited and to the City of Grande Prairie. Jones' report of October, 1960, was included as an appendix to Stanley, Grimble and Roblin's 1961 report to the City of Grande Prairie. Jones' report made certain predictions based on the pump-test results, and presuming the terrace to consist of clean coarse gravels; the primary prediction was that wells spaced 500 feet apart yielding 200 gallons of water per minute were feasible with a 15-foot thickness of water-bearing gravels. It was made clear, however, that (1) the rate of recharge of river water was not established (2) the amount of drop of water level of the river to low stage was not known, and therefore that records of stream flow were needed. The report stated that wells yielding 200 gallons per minute or substantially more were quite likely and recommended "a thorough test-drilling and pumping test program for the terraces ... if any large supply of water is desired." The pumping-test requirements were outlined, i.e. minimum length of test: 48 hours; minimum pumping rate 200 gpm (gallons per minute); recording of water temperature and water levels, and the taking of water samples for analysis. "Properly carried out the above should give all the necessary information regarding proper well field design and completion." (p. 14) The final sentence of the summary, reiterates that, based on present information from the Grovedale tests, 3 wells spaced 500 feet apart and pumped at 200 gpm would yield 864,000 gallons per day, and that additional wells would increase this supply.

The City of Grande Prairie was interested in these results and it was stated at the 1960 Groundwater Advisory Committee meeting that the City would develop wells in the aquifer. Thus in the fall and winter of 1961-62 a test-site was established on the site of the present well field, and a 3-day pump test was carried out in October, 1961, supervised by the Research Council. Mr. Jones examined the resulting data and commented on them to the City Engineer (letter Nov. 10, 1961). He concluded (1) that the well being tested was inadequately developed as the water level in the well dropped more than anticipated (2) that as the water levels had not stabilized 72 hours was too short a time for the pumping test (3) that the permeability of the terrace was good, although somewhat less than that of the terrace south of the river. Recommendations were for (1) better development of the well, (2) a longer pumping test at a higher pumping rate, (3) sampling of the water pumped out. All of the 1960 recommendations were followed in this test except for the pumping rate, which was at 60 gpm instead of the recommended 200 gpm. The results of the October 1961 test were also included in Stanley, Grimble and Roblin's report to the City. Dr. Stanley's accompanying letter of Dec. 14, 1961, however, recommended the installation of infiltration galleries on the basis that these would be less expensive than a well field. The estimates of permeability of the gravels by Mr. Jones were used as an indication of the feasibility of infiltration galleries.

The City of Grande Prairie, however, decided in favor of a groundwater well-field; this decision was probably made in part because of the claim of the city engineer that he could construct wells at costs below that of commercial firms and also because Mr. Jones remained quite optimistic about the groundwater potential of the terraces. Thus, in the fall and winter of 1962-63 the City constructed a 9-mile pipeline to the Wapiti River and built a water treatment plant; this went into production in June, 1963. Initially 3 wells were constructed 300 feet apart, about 20 to 30 feet from the river bank. At this time Mr. Jones was still of the opinion that 150-200 gpm capacities for these wells were quite feasible, but notes in his manuscript report (December, 1963) that yields drop to 120 gpm with the low stage of the river. The iron content of the water remained high, but this was expected to drop with time to that of the river water.

Mr. Jones resigned from Council in December, 1963, to move to Nova Scotia. At the time of his departure he obviously anticipated no major problems with the groundwater supply from the terrace and was inclined to attribute the less-than-expected well yields to poor well completion or to inadequate well development.

To summarize to this point: the geological situation is quite comparable to that in a number of localities in the United States where adequate water supplies have been obtained from terrace gravels. The development thus appeared straightforward even before test drilling was carried out. It is only within the last few months that mention has been made in print of a similar problem in the United States, wherein actual well yields from a terrace gravel were substantially less than those anticipated. The reason given for this is the same as that for the Grande Prairie situation — that the interstitial space between the gravel is filled with silt so substantially reducing permeability and water yield. Obviously, had this publication been available in 1960 it would have served as a warning of a potential problem.

Interpretation of data from the 1960 and 1961 pump tests was based on formulae now recognized as being inapplicable to the particular situation (as indicated in D. H. Lennox's re-evaluation, July 1965). Interpretation predicted a very good potential, and although in the second test it is now apparent that much poorer well yields were indicated, with the optimistic outlook then extant, this was attributed to poor well development. The use of an inapplicable formula was a definite error, based on the lack of experience with a variety of river terrace situations; however, it is doubtful that any other organization in Canada could have given better advice at that time.

As indicated in Mr. Lennox's July 1965 report, a third, 3-day pump test was carried out in July 1964 in an attempt to re-evaluate the potential of the terrace. The test suffered from various shortcomings and was not conclusive. The fourth test, 23 days in length, was conducted in January and February, 1965 by Stanley, Grimble and Roblin Limited. This was the first relatively complete test, and for the first time it became apparent that there was no significant induced infiltration of water from the river into the terrace gravels. The maximum pumping rate of the wells was determing to be about 50 gpm – less than half that originally anticipated.

The fifth test, from March to June, 1965, evaluated the possibility of artificial recharge pits to supplement the water in the terrace gravels. This indicated the possibility of supplementing well yields up to about 100 gpm, but as substantial additional maintenance costs would be involved, this did not appear to be an entirely satisfactory solution.

Mr. J. McLaughlin, M.L.A. for Grande Prairie, approached the Government on behalf of the City in the spring of 1965, to discuss the water supply problem. Following this meeting Mr. D. H. Lennox of the Research Council re-evaluated all available pump-test data, pointing out the incompleteness of the first three tests, but recognizing that the fourth test indicated no significant recharge of water from the river into the terrace gravels. In his report (July, 1965) it was recommended that testing of bedrock aquifers adjacent to the terrace be carried out, with the hope of supplementing the water supply obtained from the terrace. This recommendation was made with the anticipation that this would be the least expensive solution.

However, at a further meeting, with Hon. H. E. Strom and Hon. A. R. Patrick in September, 1961, the Research Council withdrew this recommendation, after taking into account the time involved in the proposed testing program, the immediacy of the problem, and the possibility that the bedrock aquifers might not yield an adequate water supply for future demands. Instead, Council was prepared to support the proposal of Stanley and Associates Limited for a direct intake supply from the Wapiti River, which guarantees an adequate water supply despite any other disadvantages.

Summary of salient points

The Research Council believed in 1959 and 1960, before any test drilling was carried out, that a water supply by induced infiltration from the Wapiti River terraces was a straightforward development: this belief was based on consideration of the geologic situation.

Predictions made in late 1960, based on a preliminary pump test, were that substantial groundwater supplies could be obtained. A pump test in 1961 was considered to support these predictions; although somewhat less amounts of water were indicated, this was believed due to the well being poorly developed. Recommendations were made nevertheless that further pump-testing be carried out.

In 1962 the City of Grande Prairie constructed 3 wells and a pipeline to supply water to the city, although no further pump test were carried out until late 1963. It is not known whether Mr. J. F. Jones of the Research Council attempted to persuade the City to carry out further pump testing before the pipeline was constructed, although he definitely recommended this in 1961. It is clear that Mr. Jones was still optimistic concerning this situation at the end of 1963 when he left Council. On the other hand, it would be noted that Council's involvement was such that it could not demand that the City carry out further pump testing before building the pipeline and treatment plant.

Shortly after the City's wells went on production in June, 1963, it became apparent that well yields were substantially less (One-third to one-quarter) than the minimum predicted. Additional wells were drilled, which failed to resolve the problem. The first complete pump test was carried out in January, 1965, and this indicated clearly the essential lack of recharge from the river into the terrace gravels. No literature published prior to the summer of 1965 indicated that such a situation could be expected, i.e. terrace gravels being silted up sufficiently to prevent recharge from an adjacent river.

MEMORANDUM

RESEARCH COUNCIL OF ALBERTA, UNIVERSITY OF ALBERTA, EDMONTON

TO Mr. John Jones,
C/O Dept. of Geology, University of Western Ontario, London, Ontario.

FROM R. N. Farvolden

DATE November 3, 1959.

Dear John:

Thanks for sending along the photos. The picture of the Wapiti formation along the river is excellent, but the buried gravel picture is out of focus. The scene from the Experimental Station doesn't show the relief as I had hoped it would, and so rather than use just one photo, we will not bother with them at all for this publication. I am sending them all back to you.

The report is coming along well and is almost ready for final (?) typing. We will let you see a copy of it.

Did you notice the article on Medicine Hat in a recent "Financial Post"?

Regards from everyone here.

Bob

RNF/G
enc

Dr. Don Stanley was in about Grande Prairie. He is doing a survey and writing a report for the town. He says he doesn't think a pipeline to the Wapiti will be economic unless g w can be developed at the min.

I suggested. 1. Explore the gravel bars along present channel.
2. Test drill across wide valley between G P and uplands to the west of city, along highway (possible buried gravels)
3. Check possibilities of artificial recharge.

and told him you'd be back in the spring. He'll likely be in touch after this winter. He doesn't expect to make a final report to G-P. till spring so there's a likelihood that you'll be back before a

February 22, 1960.

Honourable A. R. Patrick,
Chairman,
Research Council of Alberta,
Legislative Building,
EDMONTON, Alberta.

Dear Mr. Patrick:

Re: Newspaper Report on Grande Prairie Water Supply

In the Saturday, February 20 edition of the "Edmonton Journal" a report appeared which indicated that the Research Council was prepared to enter a financial arrangement with the Town of Grande Prairie to search for water along the Wapiti River. I regret very much that this report got into the papers, as it is an incorrect statement of our position in this matter.

Some time ago I met with the Town of Grande Prairie and with Dr. D. Stanley, their consultant engineer. At that time I was asked if Council could aid the Grande Prairie program and I promised to study the matter and give him a reply as soon as possible.

On February 9 I wrote a letter to Dr. Stanley outlining the view of Council, which was much the same as the attitude taken towards the Red Deer situation (see attached copy of letter). As you will note, we promised technical assistance but not a financial arrangement for the actual drilling since such a project does not fit in with our research planning.

On February 11 Dr. Stanley forwarded a copy of my letter to Mr. F. W. Beairsto, City Engineer, Grande Prairie, and thus the Town had our reply well in advance of the newspaper report on February 20.

This report will undoubtedly bring a deluge of requests from other towns, which is exactly what we did not want. I regret if this newspaper report causes the Government embarrassment and I can only state that it was given to the newspaper without either the consent or knowledge of Research Council personnel.

Sincerely,

C. P. Gravenor,
Chief, Earth Science Branch.

CPG/G
enc.

Research Council
File 22

February 10th, 1960

Hon. A. R. Patrick,
Chairman, Research Council of Alberta,
Department of Industry and Development,
Legislative Building,
Edmonton, Alberta.

Dear Mr. Patrick:

This will follow up our conversation of this morning in connection with the interest of cities in having drilling programs underwritten by Council. You will probably by now have received a memorandum addressed to me from Dr. Gravenor and forwarded to you for your information in regard to the Red Deer matter.

Attached herewith is copy of letter addressed by Dr. Gravenor to Dr. D. Stanley of Stanley Grimble Roblin Ltd. who were in on their meeting with the Grande Prairie people. While the situation is not exactly analogous to the Red Deer one, nevertheless, there is quite a bit of information on water saturated gravel in the Grande Prairie zone, consequently it is Dr. Gravenor's feeling that there is not enough research aspect in this matter to justify Council to make a commitment to underwrite any drilling program.

I trust this will help to keep you informed of the developing situation.

Yours very sincerely,

N. H. Grace
Director

NHG/BWB

RESEARCH COUNCIL OF ALBERTA

87TH AVENUE AND 114TH STREET
EDMONTON, ALBERTA, CANADA

February 9, 1960.

Dr. D. Stanley,
Stanley Grimble Roblin Ltd.,
8902 - 99 Street,
EDMONTON, Alberta.

Dear Dr. Stanley:

I have now had the opportunity to discuss the Grande Prairie water-supply proposal with members of our Groundwater staff and it is our opinion that it does not fall within the scope of our projected contractual arrangement. Our decision is based upon the following factors:

(1) One of the stipulations contained within the projected aid program is that the programs must have research value. In general, therefore, a particular project must be considered within the framework of our overall assessment of the groundwater resources of the Province and methods by which the water can be most efficiently obtained. In the case of Grande Prairie the problem is quite straightforward and does not form a part of our research program in the foreseeable future.

(2) One of the purposes of the aid program is to remove the burden of risk from a smaller community where the supply is doubtful. In the case of Grande Prairie the information you now have on the water-saturated gravel would suggest to us that the risk is not great in obtaining a suitable supply.

I believe you can see that if we accepted the Grande Prairie proposal we would be in a very awkward position with respect to the wishes of other towns in the Province. In addition, the acceptance of all projects would mean that our entire staff would be absorbed in routine matters and not fulfilling their obligations to the long-term aspects of groundwater development and research.

Although we cannot enter a financial arrangement with Grande Prairie, we can nevertheless offer technical service to your program. If so desired we can recommend a drilling program, methods of completion of test wells, run the field hydrologic tests and make the interpretation. Because our man who looks after the Peace River country is now away obtaining an advanced degree at the University of Western Ontario, we could not promise to have a man on the site before late spring or early summer.

If you wish to go ahead at an earlier date, however, we shall do our best to give whatever assistance we can to this program in the form of designing the test program and interpretation of results.

Sincerely,

C.P.G.

C. P. Gravenor,
Chief, Earth Science Branch.

CPG/G

1961-8

WATER SUPPLY STUDY

PREPARED FOR

THE CITY OF GRANDE PRAIRIE, ALBERTA.

DECEMBER, 1961

STANLEY, GRIMBLE, ROBLIN LTD.
Consulting Engineers

Edmonton, Calgary, Saskatoon
Penticton, Vancouver

STANLEY, GRIMBLE, ROBLIN LTD.
CONSULTING ENGINEERS
MUNICIPAL - STRUCTURAL - INDUSTRIAL
EDMONTON - CALGARY - SASKATOON - PENTICTON - VANCOUVER

D. R. STANLEY
B.Sc., S.M., S.D., P.Eng.
L. G. GRIMBLE
B.Sc., M.Sc., P.Eng.
H. L. ROBLIN
B.A.Sc., P.Eng.

8908 - 99 STREET
EDMONTON, ALBERTA
TELEPHONE GENEVA 9-3907

December 14, 1961.
Job. No. 224-1

LETTER OF TRANSMITTAL

Mayor & Council,
City of Grande Prairie,
Grande Prairie, Alberta.

Gentlemen:

Pursuant to your instructions, we have carried out a study of water supply for the City of Grande Prairie, and we are submitting our report herewith.

Your original letter of March 16, 1957, instructed us to prepare "----- a report on the Town water resources as represented by Bear Lake and the local Town Reservoir." We were subsequently asked to stop further work on the study, until Council had a chance to review the situation. In your letter of August 27, 1959, the scope of the report was expanded somewhat by the Council's resolution, "That Stanley, Grimble, Roblin Ltd. be authorized to complete their 1957 report on water resources for the City, and that such report include a recommendation as to the next major step required to insure an adequate water supply for the City."

By expanding the scope of the study, it became possible to consider the Wapiti River and groundwater as possible supply sources, as well as Bear Lake.

Data pertinent to the Bear Lake drainage area had been gathered previously and was submitted to the City as an interim data report on November 18, 1957. Excerpts from this report are included as an appendix hereto.

The possibility of utilizing groundwater for City supply was examined only cursorily as all indications held little hope of obtaining water in this manner, Furthermore, a great deal of money might have been required to fully investigate such possibilities.

Use of the Wapiti River as a source of water for the City raises the question of how to obtain the water from the river. The three possibilities considered were screened wells in the gravel terraces adjacent to the river, infiltration galleries under the river, and an intake structure in the river.

The Research Council of Alberta was approached for help in assessing the ground water potential of the Wapiti River Valley. Consequently, in the summer of 1960, the Research Council did some test drilling along the Wapiti River. In 1961, the City of Grande Prairie, in conjunction with the Research Council established a test well site on the north side of the river, directly south of the City. As a result of these tests, the conclusion was reached that sufficient ground water would be obtained from these gravels to supply the long range requirements of the City of Grande Prairie. The results also indicated that infiltration galleries could be used successfully.

The actual alternatives considered in detail were:

I Expansion of the existing treatment plant, utilizing Bear Lake water.

II Wapiti River Water

A. Shallow wells in the river valley.

(1) with diatomaceous earth filters for iron removal.

(2) with aeration & pressure sand filters for iron removal.

B. Infiltration galleries

(1) assuming no iron removal required.

(2) with diatomaceous earth filters for iron removal.

C. River intake with complete treatment at the existing plant.

The following table is an economic comparison of the various alternatives over the next twenty years. Annual capital and operating costs, as well as the estimated unit cost of water are shown. The annual capital costs are based on twenty-year six-percent debentures.

Alternative	Item	1960	1962-66	1967-71	1972-76	1977-81
I Expansion of Existing Facilities	Cap.Cost/yr.	$ 7,350	$25,550*	$25,550*	$29,750*	$22,400
	Op. Cost/yr.	34,660	34,700	40,900	49,200	60,400
	Total	42,010	60,250	66,450	78,950	82,800
	Cost/1000 gal.	$ 0.36	$ 0.375	$ 0.315	$ 0.29	$ 0.225
II A (1) Wells at the river with diatomile filters for iron removal	Cap. Cost/yr.		$41,350*	$41,350*	$50,750*	$43,400
	Op. Cost/yr.		25,900	33,800	48,000	65,600
	Total		67,250	75,150	98,750	109,000
	Cost/1000 gal.		$ 0.42	$ 0.36	$ 0.36	$ 0.30
II A (2) Wells at the river with aeration and sandfilters for iron removal	Cap. Cost/yr.		$46,250*	$46,250*	$58,450*	$51,100
	Op. Cost/yr.		24,200	31,600	45,300	62,000
	Total		70,450	77,850	103,750	113,100
	Cost/1000 gal.		$ 0.43	$ 0.37	$ 0.38	$ 0.31
II B (1) Infiltration galleries with no iron removed	Cap. Cost/yr.		$38,150*	$38,150*	$45,250*	$37,900
	Op. Cost/yr.		22,800	30,000	43,000	59,300
	Total		60,950	68,150	88,250	97,200
	Cost/1000 gal.		$ 0.38	$ 0.325	$ 0.32	$ 0.27
II B (2) Infiltration galleries with diatomite filters for iron removal	Cap. Cost/yr.		$41,350*	$41,350*	$46,050*	$38,700
	Op. Cost/yr.		25,900	33,800	52,200	69,800
	Total		67,250	75,150	98,250	108,500
	Cost/1000 gal.		$ 0.42	$ 0.36	$ 0.36	$ 0.30

* $7,350 of existing capital costs per year included in these items.

The use of a river intake with complete treatment facilities has not been included in the table, as preliminary calculations showed that it is a much more expensive alternative.

The costs per thousand gallons shown in this table give an indication of the cost of water delivered to the distribution system at system pressure for each alternative. The maximum increase in cost over the present figure of 36 cents per thousand gallons is 7 cents. Therefore, for a residential service which utilizes say 3000 gallons per month, the added cost would be about 21 cents per month, if the most expensive alternative were adopted.

After consideration of the various alternatives, it is recommended that the use of infiltration galleries at the Wapiti River be considered as the first choice, for the following reasons.

1. When calculating the power costs for the long supply line alternatives, a unit cost of 2.2 cents per KWH was assumed, after preliminary talks with Canadian Utilities Ltd. This leads to annual power costs of from $15,000 in the periof 1962-1966, to $49,000 in the periof 1977 -1981. If this power cost could be reduced to say 1.5 cents per KWH, which we feel is quite possible, the yearly power costs would be reduced 30%, thus bringing the total yearly costs utilizing infiltration galleries without iron removal to a lower figure than the alternatives of increasing the existing treatment plant.

2. Even if it is found that iron removal is required for the water obtained from the galleries, the cost per thousand gallons would only be 2 to 3 cents higher than that involved in expanding the existing plant, provided the power-rate reduction can be obtained. It is felt that the added security of having the existing treatment plant left as an emergency source of supply is worth the slight additional cost. This standby source could prove very valuable if a sudden increase in growth and water consumption in Grande Prairie occurred, as it could postpone another major capital expenditure for a periof of up to five or six years.

3. When looking further into the future than the expected 1981 flows, it can be seen that the existing treatment plant, if expanded now, would have to be expanded again when this consumption is reached. The supply from the Wapiti River, could however, be supplemented by the existing plant, as mentioned previously, or more water could be obtained through the proposed 10 inch diameter supply line by adding another booster station. This latter method would be particularly attractive if the power rates decreased.

4. Although water quality might rule out the use of shallow wells in the gravel terraces, because of the high hardness content which would not be filtered out by the iron removal equipment, the infiltration galleries can be expected to give water of about the same hardness as the river. This water, which has an average hardness of 160 parts per million (by weight), compares quite favorably with the present treated water of about 125 parts per million hardness.

5. The use of water from the Wapiti would provide an alternate water resource, and establish the right of the city of Grande Prairie to use this source.

As a result of our investigations, we would recommend that the following action be taken by the City of Grande Prairie.

1. That negotiations be started with the power company, Canadian Utilities Ltd., to determine how low a power rate might be obtained for this project.

2. That possible methods of obtaining water from the Wapiti River by induced infiltration be explored. These would include the Ranney Method or a perforated intake pipe installed a few feet below the river bed.

We wish to acknowledge the cordial assistance received from the City Engineer Mr. F.W. Beairsto, and from members of the waterworks staff.

Respectfully submitted,

D.R. Stanley, P. Eng.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

GLOSSARY OF TERMS

parts per million (ppm)	- the number of pounds of a given substance in a million pounds of water.
gallons per minute (gpm)	- wherever this term is used in this report, it shall denote Imperial gallons.
acre - foot	- an acre-foot is the volume of water required to cover one acre to a dept of one foot. It is equal to approximately 270,000 gallons.
diatomaceous earth filters	- filters which use diatomaceous earth, or the skeletons of small uni-celled organisms, for a filter medium.

INTRODUCTION

The original water works system for the City of Grande Prairie obtained its water supply from wells located in the community. However, the quantity of water available from these wells was very limited and not sufficient to supply the community as it expanded. As a result the city commenced construction of a water storage reservoir and a water treatment plant at Bear Creek. A plant and a new supply was completed in the spring of 1947. The original treatment plant had a capacity of approximately 140 gallons per minute and in 1954 it became apparent that this plant was becoming overloaded and would need expanding. The supply from Bear Lake and Bear Creek appeared to be adequate for some time in the future, so that expansion of the plant was justified. A very preliminary examination of other supplies such as the Wapiti River indicated that at that time it would not be economical to obtain a supply from other sources. Therefore in 1955 the water treatment plant was expanded.

In the meantime the Council of the City became well aware of the fact that it would be advisable to make a study of the long range water requirements of the City of Grande Prairie so that plans could be prepared for meeting the future needs of the community. As a result, in a letter dated March 16, 1957, this firm was authorized to make an investigation and prepare a report on the alternate water supplies available to the City of Grande Prairie and to make recommendations regarding the course of action to provide for their long range requirements. This study was started in 1957 and some work was done on the investigation of surface supplies. However Council requested this firm to discontinue work on it until further notice, and investigations were subsequently postponed until 1959 when a regular sampling of the Wapiti and reservoir water was commenced.

As a result of these preliminary investigations at the Wapiti River the possibility of obtaining ground water in the gravels along the River was revealed. This matter was discussed with the Research Council of Alberta, which became quite interested in the potential of this type of supply. The Research Council than undertook a programme to ascertain the potential of the gravels along the Wapiti River and close contact was maintained with them to assess this source of supply for the City of Grande Prairie.

Our report is submitted herewith, under the following headings:

Section I	- General
Section II	- Water Supply from Bear Lake
Section III	- Water Supply from the Wapiti River
Section IV	- Conclusions & Recommendations

SECTION 1

GENERAL

A. Description of Existing Facilities.

The present water supply of the City of Grande Prairie is from Bear Creek, which drains a water shed of 561 square miles area extending northwest from the city. Within this drainage area are numerous lakes, the most important and biggest one being Bear Lake, with a surface area of roughly 7,500 acres. At the present time the water level in Bear Lake is regulated by a dam built by "Ducks Unlimited". At the present time the live storage available in Bear Lake is considerably reduced by silt deposits formed in the Lake outlet, with only about 1-1/2 feet, or 10,000 acre feet of water available as live storage. This could however be improved by slightly raising the log dam and dredging the silt accumulated in the outlet.

Bear Creek, a meandering stream, transmits the water from Bear Lake to the south, and drains finally into the Wapiti River. In the northwest section of the City a earth dam has been built across Bear Creek, imponding about two hundred and ten million Imperial gallons of water. An 8 inch raw water line transmits the water from the storage reservoir to the water treatment plant. The original water treatment plant consisted of sedimentation basins and two concrete filters. In 1954 the plant was remodelled and expanded to a capacity of 360 Imperial gallons per minute. A solids contact unit with the capacity of 360 gallons per minute and two sand filters each with a capacity of about 140 Imperial gallons per minute were added and the sedimentation basin was transformed into a clear well. Because of the limited funds available at the time of the construction, all valves were left with manual operation. In later years dry chemical feeders, a gas chlorination unit, a fluoride feeder, carbon feeder, and an activated silica feeder were added, and new laboratory and chemical storage facilities were constructed.

The treatment process at the present time is as follows:

The water enters the treatment plant through the 8 inch transmission line from the reservoir into a sump located in the basement of the plant. At the outlet of the pipeline is a float-controlled valve which opens whenever the water level in the sump drops. The flow from this sump is through a concrete trough in the floor of the plant. Chemicals, proportioned by dry chemical feeders located on the main floor are added in the concrete trough. The low lift pumps each with the capacity of about 200 Imperial gallons per minute lift the water from the pump well into the solids contact unit located in the new part of the plant. This reactor has a designed capacity of 360 Imperial gallons per minute. In this reactor the coagulation and sedimentation of the solids takes place. A timer operates blow-off valves, and excess sludge from this unit is blown off in regular intervals. In order to increase the capacity of this unit and improve the sedimentation, activated silica is added in the center-part of the tank. In order to reduce the taste and odour of the water, activated carbon is added to the effluent from the solids contact unit.

There are four filters available at the present time, with two reinforced concrete filter tanks installed in the original plant, and two new sand filters housed in steel tanks. The combined capacity of the new filters amounts to 280 Imperial gallons per minute, with the balance of the filter capacity being provided by the two old concrete filters. Depending on the quality of the solids contact unit effluent, the [illegible] intervals of time. Back washing is done by a 1,000 Imperial gallon a minute back wash pump which draws water from the clear well. The waste water is conducted from a sump to a 12 inch storm sewer. Chlorination and fluoridation is provided before the water is discharged into the clear well. Two high lift pumps with a combined capacity of 600 gallons per minute pump the water through the distribution system into a 750,000 gallon elevated stand pipe which floats on the system.

The following controls are provided: The flow of raw water being pumped to the solids contact unit is measured by the pressure differential over a orifice plate, and fluoride is fed proportionally to this flow. The amount of treated water being pumped from the treatment plant is recorded on a flow meter. Also, the water level in the storage stand pipe is transmitted to the water treatment plant and is automatically recorded.

The laboratory is well equipped, and residual chlorine tests, fluoride tests and coagulation tests are performed regularly.

As mentioned previously all valves have to be operated manually, which makes back washing and plant operation in general rather inefficient.

With a solids contact unit capacity of 360 gallons per minute the daily plant capacity would be rated at about 430,000 Imperial gallons, considering twenty-hour operation period, which provides for back wash time, down time etc.

Observation of the 1961 records indicates that the rated capacity of 430,000 Imperial gallons per day has been exceeded on eighteen days during the month of June, on twelve days during July, and on twenty one days during August. The highest recorded daily pumping figure in this period was 515,000 Imperial gallons. To produce these excess quantities of water, very close supervision of the process, and a somewhat increased amount of chemicals is required.

From the above consideration it is obvious that the present plant is overloaded during the summer months and it has to be expected that the quality of the treated water will be subsequently lowered.

B. Future Water Demand

To estimate the future water demand of the community a number of items must be considered. Among these are the present water consumption, the present and future population, the predicted future per capita consumption and the possible industrial development.

(1) Population Trends

The population growth of cities, such as Grande Prairie is very hard to estimate for a variety of reasons. If, for instance, a single large industry were to establish therein, the effect on the population of the community could be large indeed.

For purposes of this study, growth patterns of cities which have already passed through a similar stage of development to Grande Prairie were plotted. This information, coupled with the high rate of population growth in Grande Prairie during the past ten years, led to the design of a population growth curve as shown on Figure 1.

It is possible, however, that the degree of industrial expansion in the Grande Prairie area could cause a deviation from the expected growth curve, which is based on industrial expansion equal to that which has occurred during the past ten years.

(2) Water Consumption

Table No. 1 is a record of both treatment plant output and metered consumption for the years 1959 and 1960. In this table the water consumption for the years 1959 and 1960 has been broken down into types of usage and has also been listed in terms of Imperial gallons per capita per day for the total population of the city, rather than the connected population.

TABLE 1

1959 & 1960 WATER CONSUMPTION

Population	1959 - 7900 (assumed)				1960 - 8000			
	Mil. Gals.	Gal/cap/ day	Avg. Day Mil. Gal.	Max. Day. Mil. Gals.	Mil. Gals.	Cal/cap/ day	Avg. D. Mil. Gal.	Max. D Mil. Gal.
Industrial					8.6	2.9		
Commercial					32.6	11.2		
Residential					47.4	16.2		
Public					10.9	3.7		
Lose & Waste	9.2	3.2			17.4	6.0		
Total	98.1	34.0	.269	.509	116.9	40.0	.319	.518
			ratio = 1.89				ratio = 1.62	

From the above table, Table No. 2 has been developed, which shows the expected per capita consumption for the years 1971 and 1981. One item is of particular interest on this table. The residential per capita consumption is assumed to rise quite rapidly during the first ten year period, after which a certain levelling off has been indicated. This is to be expected because a greater percentage of the populace will probably become connected to the water system in the near future. Also, with improving housing standards, it is expected that many new automatic washing facilities, and other water using conveniences will increase in number quite rapidly.

TABLE 2

EXPECTED 1971 & 1981 WATER CONSUMPTION

Population	1971 = 13,200				1981			
	Mil. Gals.	Gal/cap/ day.	Avg. Day Mil. Gals.	Max. Day Mil. Gals.	Mil Gal.	Gal/cap/ day	Avg. Day. Mil. Gals.	Max. Day Mil. Gals.
Industrial	39	8.0			66	10.0		
Commercial	58	12.0			80	12.0		
Residential	120	25.0			200	30.0		
Public	24	5.0			33	5.0		
Lose & Waste	19	4.0			27	4.0		
Total	260	54.0	.712	1.28	406	61.0	1.11	2.00

(3) Effect of Industry on Water Consumption

As indicated previously, one of the ways in which the establishment of a large industry can effect water consumption is through the population growth required to run the industry.

In addition to this, the industry can affect water consumption by direct usage. For example, the oil refinery in Dawson Creek, B.C. utilized some 94,000,000 gallons of water during 1959. If this type of wet industry were to establish itself in Grande Prairie it would immediately almost double the city's 1960 consumption. This occurrence has not been considered in the table of predicted consumptions.

(4) Assumed periods for water supply development

In choosing a practical and economical design period for water works installations, there are a few conditions which should be taken into account. Firstly, the expected rate of growth must be considered. If a community is developing rapidly, the design period should be kept relatively short, as the capital cost of providing facilities for a long design period initially be beyond the resources of the community.

Secondly, the ease with which additions may be made to the initial installation has some bearing on the design period. If additions can be included at a later date, and still be economical and efficient, the first stage of development may be designed to serve for a shorter period.

A third point to be considered is the physical life expentancy of the installed facilities. There is little point, for instance, in designing a treatment plant for fifty years, if the life expentancy of the plant is only thirty years.

In this report, all major structures and components have been designed to deliver the 1981 maximum daily flows in less than 24 hours. However, mechanical equipment and apparatus within the structures will be sized to suffice until 1971 only. At that time, the added equipment necessary to deliver 1981 flows will be installed within the structures.

C. Possible Sources of Water Supply

The following sources of water for the city of Grande Prairie have been considered:

1. Surface water from the Bear Lake drainage basin.
2. Ground water
3. Wapiti River water

1. Bear Lake Drainage Area

This source of water is presently being used by the City of Grande Prairie as outlined under Subsection A above. In November, 1957 an interim report was prepared by this firm which contained data pertinent to establishing the adequacy of this source of water for future demands. Parts of this data are contained in Appendix I of this report.

Consideration of this data will be presented in a later section.

2. Ground water

Ground water has been used in the past as a source of water supply for the City of Grande Prairie. This source was subsequently abandoned, however, when it proved inadequate for the increasing population of the community.

No extensive test drilling program has ever been carried out in the vicinity of Grande Prairie. Therefore, no definite conclusion as to the avilability of ground water can be made. However, the Research Council of Alberta indicates that the probability of finding a suitable supply from this source is small indeed. This alternative has therefore not been included in this present study.

3. Wapiti River water

The Wapiti river, lying some six miles south of the City of Grande Prairie, is another logical source of water supply for the needs of the city. Three methods of obtaining water from the river will be discussed within this report, namely: wells in the gravel terraces bordering the river; infiltration galleries under the river; and a river intake.

D. Water Quality of Supply Sources

When comparing various sources of water supply one of the most important aspects which must be considered is that of water quality. In addition to it being important to the residential consumer, some industries rely upon a certain standard of water quality for use in their manufacturing processes. The ease with which the industry can obtain the required water quality sometimes dictates where that industry will locate. Appendices II, III, IV and V are results of analyses performed on samples of water from the various sources being considered. Figure 2 shows graphically the mean values of both iron and hardness content as represented by the water analyses reports.

The following observations can be made from the water qualities shown in Appendices II, III, IV, and IV.

(1) In the Wapiti River, hardness fluctuates highly (from 85 ppm to 230 ppm), but with no set pattern of seasonal variations. The iron content appears to generally be lower during the winter months. Total solids in the test samples fluctuates from 160 ppm to 346 ppm, again with no apparent seasonal pattern. Visual observation of the river would probably show a much higher color and turbidity count during spring runoff than at other times of the year.

(2) Reservoir test samples indicate that total solids, iron, and hardness reach their maximum values just before spring runoff occurs, and are at a minimum in the late spring and summer.

(3) Although tests of the well water from the Wapiti River gravel were only performed on samples taken in October, 1961, it is expected that the high iron and hardness content would be without any marked seasonal fluctuation. It is quite probable however, that a general lowering of these valves would be experienced if a long period of continuous pumping was undertaken.

SECTION II

WATER SUPPLY FROM BEAR LAKE

A. Quantity and Reliability of Water Supply

It is quite evident that under present conditions, the water reservoir at the treatment plant is more than adequate to satisfy the needs of the community. In 1958, for instance, the water elevation in the reservoir drew down only two and one-half feet between November 14, 1958 and March 16, 1959 even though no water was transferred from Bear Lake to the reservoir during this period. It is expected that by 1971 water consumption will be about triple that of 1958. We can, therefore, assume that at that time the reservoir would be lowered about eight feet over the period of one winter if no water was admitted from Bear Lake. This would bring the water level quite near the danger point for proper operation of both the city and the refinery water intakes.

Because of the shallow conditions which exist in the channel behind the small dam at Bear Lake, complete freezing of the channel occurs during the winter. Therefore, under present conditions water cannot be released from Bear Lake during the winter to replenish the storage in the reservoir.

If this condition could be eliminated, however, no problem arising from insufficient water supply should be expected. Table No. 3 which has been developed from data contained in Appendix No. I indicates that the Bear Lake drainage basin is quite capable of supplying water for many years in the future if it's outlet can be properly controlled.

TABLE 3

BALANCE SHEET FOR STORAGE IN BEAR LAKE

(using 1981 demand figures)

Month	Precip. (ft.)	Usable Prec. Acre-Ft.	Evaporation Acre-Ft.	Demand Acre-Ft.	Storage Acre-Ft.	Storage Change Acre-Ft.	Runoff Acre-Ft.
October	.09	5,000 (20%)	1,800	125	100,000 (ass.)	-	-
November	.10	5,300 (20%)	100	100	100,000	-	5,100
December	.06	-	100	100	99,800	-200	-
January	.22	-	250	100	99,450	-350	-
February	.07	-	250	100	99,100	-350	-
March	.03	52,000 (50%)	850	125	100,000	+900	50,125
April	.05	2,500 (20%)	1,300	125	100,000	-	1,075
May	.14	7,500 (20%)	3,900	125	100,000	-	3,475
June	.17	9,500 (20%)	4,300	150	100,000	-	5,050
July	.06	3,500 (20%)	5,600	150	97,750	-2,250	-
August	.03	1,500 (20%)	5,700	150	93,400	-4,350	-
September	.09	5,000 (20%)	2,700	150	95,550	+2,150	-
October	.09	5,000 (20%)	1,800	125	98,625	+3,075	-

Note: The percentage figures in the "Usable Precipitation" column represent that portion of the precipitation which is assumed to reach Bear Lake.

The consumptive drawdown of Bear Lake, which would occur when replenishing the reservoir during the winter months of 1981, is calculated to be less than three inches. This is based on a lake area of 7,000 acres and a consumption plus evaporation loss from the reservoir of 200,000,000 gallons.

From Appendix I it can be seen that the evaporation from Bear Lake between November and March of any year seems to vary between one and two inches. This would mean a total drawdown of Bear Lake between November and March of about five inches which is more than made up by the spring runoff from the 274,000 acre drainage basin. The main assumption made herein is that the seepage losses which occur in the lake during the winter months are negligible.

Table No. 3 also shows that for 1945, which was the driest year in twenty, evaporation from water surfaces exceeded usable precipitation in two months only. This is based on the premise that 20 percent of the precipitation which falls on the drainage basin finally reaches the lake.

From these calculations it appears reasonable to assume that Bear Lake can be replenished to high water level during spring runoff and also in most years again during September, October and November. Since there is a foot and a half of live storage available in the lake under present conditions, then even during years when the high water level cannot be obtained during September and October, there would still be more than sufficient water available for the coming winter's operation.

Table 4 shows an assumed balance sheet for the storage in Bear Lake for 1945 hydrological conditions. For the purpose of this investigation it was assumed that the live storage in the Lake would amount to 10,000 acre-feet and that 1,000 acre-feet per month are being used to fill the City reservoir. The figures for the amount of precipitation and evaporation were taken from the preceding Table 3. This table indicates that even assuming the dry conditions as in 1945, Bear Lake could be used to supply 1,000 acre-feet of water per month to the city reservoir. Assuming further that even 50 percent of this amount is lost due to evaporation in the reservoir and due to losses in Bear Creek, there would still be 500 acre-feet per month available for consumption at the City Reservoir. This allows for a consumption of 4.4 million gallons per day, which is roughly 4 times the consumption predicated for 1981. This illustrates the fact that the Bear Creek water shed is capable of supplying the demand of the city for quite some time.

The following improvements to the Bear Creek supply could be contemplated.

(a) Diversion of Grande Pràirie Creek into Bear Lake. This would increase the catchment area of the impounding reservoir and would help to decrease flood damage in the lower reaches of Bear Creek.

(b) Raising of the dam at the Lake outlet by 6 inches. This amount would increase the storage capacity by roughly 3,500 acre-feet (950 million Imperial gallons). Since the city purchased the land surrounding the lake to allow for a rise in level of 2 feet, it shouldn't be too difficult to add this additional height to the dam.

(c) Dredging of the lake outlet. This may have to be repeated possibly every 3 or 4 years in order to maintain a channel sufficiently deep for winter operation.

(d) Improvements to Bear Creek including clearing and brushing along the river banks in order to improve the flow of water.

TABLE 4

BALANCE SHEET FOR STORAGE CONDITION IN BEAR LAKE

(4.4 million gallons per day consumption)

Month	Storage at end of Month Acre-Ft.	Usable Precipitation Acre-Ft.	Evaporation Acre-Ft.	Discharge to Reservoir Acre-Ft.	Waste Acre-Ft.
September	5,000	-	-	-	-
October	7,200	5,000	1,800	1,000	-
November	10,000	5,300	100	1,000	1,400
December	8,900	-	100	1,000	-
January	7,650	-	250	1,000	-
February	6,400	-	250	1,000	-
March	10,000	52,000	850	1,000	43,750
April	10,000	2,500	1,300	1,000	200
May	10,000	7,500	3,900	1,000	2,600
June	10,000	9,500	4,300	1,000	4,200
July	6,900	3,500	5,600	1,000	-
August	1,700	1,500	5,700	1,000	-
September	4,000	5,000	2,700	1,000	-
October	7,200	5,000	1,800	1,000	-

B. Proposed Treatment Plant Expansion

In the preparation of the preliminary plans for the expansion to the water treatment plant, the following considerations governed:

(a) The ultimate total treatment plant capacity should amount to 1,400 Imperial gallons per minute. This will allow for treatment of the 1981 maximum daily flow in 24 hours.

(b) As much as possible of the existing equipment should be utilized in an economical way.

(c) The amount of plant supervision required should be reduced by providing for automatic controls.

(d) The quality of the treated water should be satisfactory for domestic and general industrial use.

Stage I will provide for a total filter capacity of 900 Imperial gallons per minute, not counting the old concrete filters which should be strictly considered as stand-by capacity. Stage II would bring the total plant capacity to 1,400 Imperial gallons per minute. In the following paragraphs both stages will be discussed in detail.

Stage I includes the construction of the building of adequate size to house the Stage II equipment. Since the increment cost for the construction of the added solids contact unit decreases rapidly with the increase in size, it is most economical to provide the added capacity in one unit. The new treatment plant addition therefore is constructed to provide for a new solids contact unit with a design capacity of 1,040 Imperial gallons per minute, which together with the old unit will add up to the ultimate required capacity of 1,400 Imperial gallons per minute. Included in the building construction are four concrete filter tanks each designed for a capacity of 275 Imperial gallons per minute.

The building will be of concrete block construction with a steel roof deck and a reinforced concrete operating floor covered with floor tile. All backwashing and normal operation will be done from the operating floor. The existing 150 gallons per minute steel filters will be operated manually through valve stands erected on the new operating floor. The new filters will have automatic consoles which will allow for pneumatic operation of all valves and automatic adjustment of the filtering rate. In the first stage only two of the new filters would be equipped with filter beds and automatic valves. The other two filters would then be completed in Stage II. The operating consoles will also have gauges indicating the head loss, the filtering rate and backwash pressure and flow rate. The automatic controls will provide for maintenance of a constant level in the solids contact unit. In Stage II they will proportion the flow to the two solids contact units according to a preset rate. The controls will assure proportional feeding of chemicals, and increase or decrease in the filter rate according to the level in the clear well.

It is proposed to re-locate three feeders in the basement as indicated on Fig. IV. in order to provide bigger hopper storage and make loading of the hoppers easier. The carbon feeder would remain where it is now and the fluoride feeder would be re-located in the same room. The feeder equipment would be modified to provide for feeding at two points in the treatment process.

The pumping equipment would be re-arranged in the way indicated on the sketch. The two existing high lift pumps and one new high lift pump with a capacity of 700 gpm will be installed in the basement of the new addition as indicated on Figure IV. A new backwash pump with a capacity of 1,700 gpm will be installed in the same room. The existing backwash pump will then be utilized as a low lift pump.

A new three phase power distribution centre will be located in the pump room and a main control centre will be erected in the present location of the fluoride feeder.

A new 10 inch supply line from the reservoir to the treatment plant will be necessary and certain revisions to the waste lines will be required.

In the second stage another high lift pump will be required. The remaining two filters will be completed and the old 360 Imperial gallons per minute solids contact unit will be brought into operation again.

Table No. 5 shows the estimated capital cost of Stage I and Stage II of the proposed water treatment plant expansion. The estimated cost for Stage I amounts to $208,900. The cost for Stage II amounts to $47,400. The cost estimates are based on 1961 prices and include engineering and contingencies.

TABLE 5

ESTIMATED CAPITAL COSTS OF WATER TREATMENT PLANT EXPANSION

Item	Stage I 1962 Construction	Stage II 1971 Construction
Building, including heating, ventilating, plumbing	$ 100,200	$ -
Equipment and pumps	74,400	33,600
Process piping	17,000	4,600
Outside piping	7,000	-
Electrical	10,300	1,200
Repairs to dam, improvements to lake outlet and channel	-	8,000
Total Costs	$ 208,900	$ 47,400
Capital Costs per year based on 20 year loan at 6%	$ 18,200	$ 4,200

Table No. 6 compares the expected yearly operating costs of the expanded water treatment plant with the actual 1960 operating costs. In 1960 a total of 117 million gallons of water had been produced at a total operating cost of $42,014 or a cost of $0.36 per 1,000 Imperial gallons. The 1960 operating costs do not include an expenditure of possibly up to $12,000 which has been spent since 1955 and which, when capitalized over 10 years, would add roughly 2 cents to the price per thousand gallons of water, increasing it from 36 to 38 cents per thousand

TABLE 6

YEARLY OPERATING COST FOR EXPANDED WATER TREATMENT PLANT

Year	1960	1962-66	1967-71	1972-76	1976-81
Population	8,000	9,300	11,200	13,600	16,500
Consumption	117 mg	160 mg	210 mg	275 mg	365 mg
Plant maintenance	$ 686	$ 1,200	$ 1,200	$ 1,500	$ 1,500
Maintenance of reservoir and channel	-	1,000	1,200	1,500	1,500
Chemicals ($80/mg)	11,555	12,800	16,800	22,000	29,200
Power	5,500	7,500	9,500	12,000	16,000
Heat	631	1,000	1,000	1,000	1,000
Lights	494	800	800	800	800
Wages	15,795	10,400	10,400	10,400	10,400
Capital Costs	-	18,200	18,200	22,400	22,400
Previous Debentures	7,353	7,353	7,353	7,353	-
Total Annual Costs	$42,014	$60,253	$66,453	$78,953	$82,800
Cost per 1,000 I.G.	36¢	37.7¢	31.6¢	29.0¢	22.7¢

gallons. In the annual operating costs the amount for maintenance of the channel, the lake outlet in the reservoir has been included. In 1960 the chemical cost amounted to roughly $99.00 per million gallons. In our operating estimates we assumed that the chemical costs could be reduced to about $80.00 per million gallons. A look at Table 6 indicates that in the future years the chemical costs will be the biggest annual expenditure and therefore a close examination of the treatment process and the application of chemicals seems well worthwhile. It is believed that the chemical cost per million gallons of treated water can be reduced out of the following reasons:

(a) Because of overloading of the solids contact unit in the present plant a higher proportion of chemicals was required per thousand gallons.

(b) Because of overloading of the filters a greater amount of backwash water had to be wasted. Treated water is being used for wash water and therefore the chemicals used for this treated water are being wasted.

(c) At the present time a comparatively great variety of chemicals have to be stocked in order to take care of emergency conditions of the overloaded equipment. In future the number of chemicals can be reduced and bulk purchases will decrease the cost further.

The labour cost includes two full time operators including wages and 15 percent for social burden.

It is interesting to note from Table No. 6 that the capital costs are not the biggest item of expenditure and that their importance in relation to the over-all cost decreases with increased water production. It is also interesting to note that there is only a very insignificant increase in cost per thousand Imperial gallons of water after construction of the new water treatment plant and that these costs will considerably decrease over the years, as the usage of water increases. In our operating cost we included an estimated amount for the annual maintenance of the reservoir and the channel. In Stage II an amount of $8,000 has been included to provide for major repairs to the dam and the lake outlet.

SECTION III

WATER SUPPLY FROM THE WAPITI RIVER

Three possible methods of obtaining water from the Wapiti River will be considered, each one of which will produce a different quality of water, which could be a deciding factor in choosing which method is best for the City (see Section ID).

Regardless of which method is used to obtain water from the Wapiti River, a supply line will be required to transport the water to the distribution system.

To determine the best size of line, calculations of yearly costs were done for 6", 8", 10", 12", and 14" diameter pipe, for expected 1971 and 1981 flows. These yearly costs included the capital cost of the pipeline plus the power costs to overcome the friction losses in the line. A unit cost of 2.2 cents per KWH of electricity was assumed. On this basis the 10 inch diameter line was found to be the least expensive at 1971 flows, while the 12 inch diameter line was found least expensive at 1981 flows. Since this transition occurs about 1976, it becomes apparent that the 10 inch diameter pipe is least expensive over the twenty year range 1961 to 1981.

A. Use of Shallow Wells in the River Valley

The use of shallow wells in the river gravels was first brought to light as a possible water source after the Research Council of Alberta obtained information from ground water investigations during the summer of 1960. Their findings are presented in part in Appendix VII.

It was recommended in the summary of the Council's 1960 investigation that further pump tests of the alluvial terraces be undertaken to establish both quantity and quality of water available in the gravel terraces. Subsequently, the City of Grande Prairie set up a well drilling and testing program during the fall of 1961. The Research Council of Alberta again took data and analysed it. Their recommendations and some data tables are included in Appendix VI.

1. Quantity of Water Available

As mentioned in Appendix VI, the results of the well pump tests conducted during the autumn of 1961 were not considered to be conclusive. The large local drawdown which occurred around the well limited the pumping rate to 70 gallons per minute. Mr. J.F. Jones of the Research Council felt that this was caused by a binding of the gravel immediately around the well screen.

Although no definite conclusion was formed from the pump test results, Research Council personnel feel that a properly developed well in the gravel terrace would yield in excess of 170 gallons per minute. For purposes of this report, individual well capacity has been assumed at 170 gallons per minute. On this assumption, six wells will be required to deliver the 1971 requirements, with four more being added to adequately serve the 1981 population.

2. Quality

As indicated by Appendix III the water obtained from the wells during the pumping test was relatively high in hardness and very high in iron content. The difference between the characteristics of this water and those of other sources of supply is shown graphically on Figure 2.

If this source of supply were used for a relatively long period of time, say a year, there is a good possibility that both the iron because both the river water to the south and the spring water to the north of this site are considerably lower in both iron and hardness than the well water. In other words, it seems as if this gravel terrace has become a store house, so to speak, for the iron and hardness. As the vegetation on the terrace utilizes the water, much of the mineral content is left behind and thus through the years this content has increased. After a long period of pumping, therefore, this storage of mineral content may be reduced and the water quality could approach that of the river, especially if the wells are placed relatively close to the river bank.

For cost comparison purposes, it shall be assumed that iron removal treatment is required. This removal would be accomplished by filtration, possibly preceded by aeration. In this regard, the relative merits of using either sand filters or diatomaceous earth filters should be studied very closely, as there is quite a difference in capital cost.

3. Alternative Locations of Iron Removal Facilities

The installation of iron removal facilities at four different locations along the supply line route have been considered herein and estimates of cost are presented for each alternative. The final choice of location can be arrived at only by considering both the yearly cost and the advantages involved.

(a) Facilities at the well site.

This alternative involves the construction and/or supply of six wells with low lift turbine pumps, aerators and filters with adequate housing, centrifugal booster pumps, and a supply line to the distribution system. The initial design would be sized to deliver

1,000 gallons per minute which is equivalent to the expected maximum daily 1971 flow being delivered in 21 hours. The filter building would however, be of such a size to accommodate the extra filters and pumps to increase the flows to 1675 gallons per minute.

When flows in excess of 1,000 gallons per minute are required, the following additions would be made: four new wells with low lift turbine pumps, added aerators and filters, added centrifugal booster pumps, and a booster station at a predetermined point in the supply line.

The estimated capital costs of this development shown in Table 7 is based upon the premise that diatomaceous earth filters may be used.

TABLE 7

ESTIMATED CAPITAL COSTS OF A WELL SUPPLY WITH DIATOMITE FILTERS

Item	1971 flows	1981 flows
Wells & housings	$18,000	$13,500
Well pumps	$17,000	$11,000
Well piping	$11,000	$ 4,500
Well electrical	$12,000	$ 4,500
Control system	$ 4,500	--
Filter housing	$ 6,800	--
Filter mech. & elect.	$31,500	$15,800
Booster pumps & elect.	$24,300	$18,000
Supply line - 33,000 ft.	$266,000	--
Booster station		$41,000
	$391,000	$108,300
Cost/yr @ 6% loan for 20 years	$ 34,000	9,400

Yearly operating costs were calculated on the basis of five year increments as shown in Table 8. Chemical costs were based on using one pound of diatomaceous earth per 5,000 gallons of water at a cost of $150.00 per ton. Power costs were based on 65% efficiency of the pumping units at a cost of 2.2¢ per kilowatt hour. Wages are based on the employment of one full time man and one part time man for operation and maintenance purposes.

TABLE 8

YEARLY OPERATING COSTS OF A WELL SUPPLY
WITH DIATOMITE FILTERS

	1962 - 65	1967 - 71	1972 - 76	1977 - 81
Population	9300	11,200	13,600	16,500
Consumption	160 mil.gal	210 mil. gal.	275 mil.gal.	365 mil.gal.
Pumping Head	800 feet.	875 feet	975 feet	1100 feet.
Maintenance & Improvements	$1,500	1,500	2,000	2,000
Chemicals	2,400	3,100	3,900	5,100
Power	15,200	21,900	32,600	49,000
Heat & Light	800	800	1,500	1,500
Wages	6,000	6,500	8,000	8,000
Capital Costs (from Table 4)	34,000	34,000	43,400	43,400
Existing capital costs	7,350	7,350	7,350	nil
TOTAL	$67,250	75,150	98,750	109.000
Cost per 1000 gals.	$ 0.42	0.36	0.36	0.30

With the iron removal equipment situated at the well site, the construction of an all weather road to the site becomes an necessity since it will probably be necessary to check the filter operation at least once per day. However, even with just the wells at this site, a possible road would be required for maintenance and periodic checking of the pumps.

A beneficial effect of this alternative is that treated water is being transported through the supply line, and thus water service is available to consumers along the supply line route.

A second estimate of cost has been prepared (see Tables 5(a) and 6(a)), which shows the costs involved if aeration and sand filters are found necessary, rather than diatomaceous earth filters. Before a final decision on the equipment is reached, it would be advisable to rent a diatomaceous earth filter test unit, to determine its effectiveness under field conditions. This unit could probably be obtained for less than $100.00 per month.

TABLE 7 (a)

ESTIMATED CAPITAL COSTS OF A WELL SUPPLY WITH AERATION and SAND FILTERS

Item	1971 flows	1981 flows
Wells & housing	$18,000	$13,500
Well pumps	$17,000	$11,000
Well piping	$11,000	$ 4,500
Well electrical	$12,000	$ 4,500
Control system	$ 4,500	
Filter housing	$22,600	
Filter mech. & elect.	$71,000	$47,500
Booster pumps & elect.	$24,300	$18,000
Supply line	$266,000	
Booster station		$41,000
	$446,400	140,000
Cost/yr @ 6% loan for 20 yrs.	38,900	12,200

TABLE 8 (a)

YEARLY OPERATING COSTS OF A WELL SUPPLY WITH AERATION and SAND FILTERS

	1962 - 66	1967 - 71	1972 - 76	1977 - 81
Population	9,300	11,200	13,600	16,500
Consumption	160 mil.gal.	210 mil.gal.	275 mil.gal.	365 mil.gal.
Pumping Head	800 feet	875 feet	975 feet	1100 feet
Maintenance & Improvements	$1,500	1,500	2,000	2,000
Chemicals	600	800	1,100	1,400
Power	15,200	21,900	32,600	49,000
Heat & Light	900	900	1,600	1,600
Wages	6,000	6,500	8,000	8,000
Capital Costs (from Table 4(a))	38,900	38,900	51,100	51,100
Existing capital costs	7,350	7,350	7,350	Nil
TOTAL	70,450	77,850	103,750	113,100
Cost/1000 gals.	0.43	0.37	0.38	0.31

(b) Treatment Facilities Midway Between the Well Site and the City.

This alternative has been considered in an attempt to reduce the yearly cost during the second stage of development. To accomplish this the filtration plant would be so placed along the supply line that it could also be used to house the booster pumps required to increase the supply to 1675 gallons per minute from the initial design figure of 1,000 gallons per minute. Preliminary calculations indicate that this desired location is at the large sand pit just south of the Bear Creek crossing. (See Figure III)

The main disadvantage to this setup is that during the first period of water needs (1,000 gallons per minute) the filters would be operating under a relatively large pressure. This condition has a tendency to compact the diatomaceous earth on the filter elements, which shortens filter runs and thus increases chemical costs. This could be avoided by installing booster pumps at the filters initially so that the pressures on the filter discharge would be negligible. This would of course increase the first stage cost, and has not been considered.

Estimates of capital and operating costs for this alternative are given below in Tables 9 and 10. Again it has been assumed diatomaceous earth filters may be used.

TABLE 9

ESTIMATED CAPITAL COSTS OF WELL SUPPLY WITH DIATOMITE FILTERS

Item	1971 flows	1981 flows
Wells & housings	$18,000	$13,500
Well pumps	44,000	29,500
Well piping	9,000	4,500
Well electrical	12,000	6,100
Control system	4,000	
Filter housing	5,600	
Filter mech. & elect	35,500	16,000
Supply line	266,000	
Booster station		36,000
	394,100	105,600
Cost/yr @ 6% loan for 20 yrs	34,300	9,200

TABLE 10

YEARLY OPERATING COSTS OF WELL SUPPLY WITH DIATOMITE FILTERS

	1962-66	1967-71	1972-76	1977-81
Population	9,300	11,200	13,600	16,500
Consumption	160 mil.gal.	210 mil.gal.	275 mil.gal.	365 mil.gal.
Pumping Head	800 ft.	875 ft.	975 ft.	1100 ft.
Maintenance & Improvements	$1,200	1,200	2,000	2,000
Chemicals	2,800	3,600	3,900	5,100
Power	15,200	21,900	32,600	49,000
Heat & Light	800	800	1,200	1,200
Wages	6,000	6,500	8,000	8,000
Capital Costs (from Table 6)	34,300	34,300	43,500	43,500
Existing capital costs	7,350	7,350	7,350	Nil
TOTAL	67,650	75,650	98,550	108,800
Cost per 1000 gals.	0.42	0.36	0.36	0.30

(c) Treatment Facilities at the South Edge of the City

For this alternative high head turbine pumps at the wells would be used to transport the water through the supply line and filters directly into the distribution system. In this case the filters would not be operating under an excessively high pressure because of the fact they would be located so close to the distribution system. Also the close proximity to the City would allow the iron removal process to be kept under surveillance much more easily. A disadvantage to this site is that no customers south of the filter site could be serviced from the supply line, as the water would be unsuitable.

It is possible that problems could be encountered in this method if the iron precipitates out of the water along the supply line route. However, it is expected that the high velocities in the supply line will keep this possibility very remote.

Estimates of capital costs and operating costs are given below in Tables 11 and 12. Again the estimates are based upon the use of diatomaceous earth filters. The estimated additional costs involved in using aeration and sand filters is as before.

TABLE 11

ESTIMATED CAPITAL COSTS OF WELL SUPPLY WITH DIATOMITE FILTERS

Item	1971 flows	1981 flows
Wells & housings	$18,000	$13,500
Well pumps	44,000	29,500
Well piping	9,000	4,500
Well electrical	12,000	6,100
Control system	4,000	
Filter housing	4,500	
Filter mech. & elect.	34,500	16,000
Supply line	266,000	
Booster station		41,000
	392,000	110,600
Cost per year @ 6% loan for 20 yrs.	34,000	9,600

TABLE 12

YEARLY OPERATING COSTS OF WELL SUPPLY WITH DIATOMITE FILTERS

	1962-66	1967-71	1972-76	1977-81
Population	9,300	11,200	13,600	16,500
Consumption	160 mil. gal.	210 mil. gal.	275 mil. gal.	365 mil. gal.
Pumping head	800 ft.	875 ft.	975 ft.	1100 ft.
Maintenance & Improvements	$1,500	1,500	3,000	3,000
Chemicals	2,400	3,100	3,900	5,100
Power	15,200	21,900	34,000	51,000
Heat & Light	800	800	1,500	1,500
Wages	6,000	6,500	8,000	8,000
Capital Costs (from Table 8)	34,000	34,000	43,600	43,600
Existing capital costs	7,350	7,350	7,350	Nil
TOTAL	67,250	75,150	101,350	112,200
Cost per 1000 gal.	0.42	0.36	0.37	0.31

(d) Treatment Facilities at the Existing Plant:

To allow the establishment of iron removal facilities within the existing plant building, it will be necessary to extend the supply line directly to the plant without connection to the distribution system. This alone adds some 9,000 feet to the supply line length. For purposes of cost comparisons, it was decided to assume that this added length of line could be run directly along the creek bed from the south edge of Town as shown on Figure III. Since this is the shortest route from the wells to the existing plant, it becomes apparent that if this method of conveying the water to the existing plant is not economical, no other supply line route will be either, as longer lengths of line will be involved.

To facilitate the establishment of iron removal equipment in the existing plant, it will be necessary for some rearrangement to be done. This will of course drastically effect the availability of using the existing plant for emergency standby purposes. With the iron removal facilities in the locations mentioned in a, b, and c above, the existing treatment plant could be maintained as an emergency source of water supply in the event of a major failure along the supply line route.

Estimated capital costs and operating costs are given below in Tables 13 and 14.

TABLE 13

ESTIMATED CAPITAL COSTS OF WELL SUPPLY WITH DIATOMITE FILTERS

Item	1971 flows	1981 flows
Wells & housings	$18,000	$13,500
Well pumps	44,000	29,500
Well piping	9,000	4,500
Well electrical	12,000	6,100
Control system	4,000	
Filter mech. & elect.	35,500	15,800
Booster pumps	10,200	6,800
Supply line	335,000	
Booster station		34,000
	467,700	110,200
Cost per year @ 6% loan for 20 yrs	40,700	9,600

TABLE 14

YEARLY OPERATING COSTS OF WELL SUPPLY WITH DIATOMITE FILTERS

	1962-66	1967-71	1972-76	1977-81
Population	9,300	11,200	13,600	16,500
Consumption	160 mil. gal.	210 mil. gal.	275 mil. gal.	365 mil. gal.
Pumping Head	800 ft.	875 ft.	975 ft.	1100 ft.
Maintenance & Improvements	$ 1,200	1,200	2,000	2,000
Chemicals	2,400	3,100	3,900	5,100
Power	15,200	21,900	32,600	49,000
Heat & Light	800	800	1,200	1,200
Wages	6,000	6,500	8,000	8,000
Capital costs (from Table 10)	40,700	40,700	50,300	50,300
Existing capital costs	7,350	7,350	7,350	Nil
TOTAL	73,650	81,550	105,350	115,600
Cost per 1000 gals.	0.46	0.39	0.38	0.32

B. Use of Infiltration Galleries

Infiltration galleries can, in general, be defined as a series of horizontal, perforated pipes radiating from a single vertical collector well. The collector well is usually placed on the shore of a body of water, with the perforated pipes running out under the body of water. The water infiltrates through gravel to the perforated pipe, which transport it to the collector well where a pump is installed.

The results obtained from pump tests leave little doubt that a sufficient supply of water can be obtained through an infiltration gallery, but there is some doubt as to the quality of water which would be obtained. It is therefore suggested that further investigations be carried out, should the Wapiti River be considered as a source of water.

These problems are discussed in detail under the following two headings.

1. Quantity of flow

According to Appendix VI, a rough estimate of the infiltration value of the gravel deposits on the north side of the Wapiti River is 2,400 gallons per square foot per day. If an 8 inch diameter pipe were layed in the gravel, every foot of the pipe would be exposed to approximately two square feet of gravel. The number of feet of pipe required to admit 1,000 gallons per minute would therefore be about 300 feet. If 12 inch pipe were used, 200 feet would be required for a flow of 1,000 gallons per minute. Because of the total lack of water supply that would occur upon failure of an infiltration gallery, two galleries, each of 1,000 gallon per minute capacity, have been considered for purposes of estimating costs.

Since the effectiveness of infiltration galleries in this location is not definitely known, it is recommended that further testing be undertaken before any large scale infiltration galleries are installed. In this regard, Ranney Method Water Supplies Inc. has been contacted and they have been asked to submit an estimate of cost for testing and reporting on the feasibility of utilizing infiltration galleries. Their initial comments will be sent as an addendum to this report, when they are received.

2. Quality of Water

As shown in Appendices II and III and Figure 2, there is a marked difference in quality of the river and well waters. Just what would be obtained from infiltration galleries under the river is hard to estimate. The worst possibility would be that water of the same quality as that obtained in the wells would be obtained initially, but with a gradual change towards the quality of the river water. There is a slight chance, however, that the water quality obtained after a certain period of time will be better than that of the river water. This condition would occur if the natural river gravels acted as a filter to remove the suspended iron content, and the colour and turbidity present in the river water.

If the latter condition does prevail, there is a / possibility that iron removal facilities will not be required. For this reason, cost estimates have been prepared both with and without iron removal facilities.

3. Alternative Locations of Treatment Facilities

As in Sub-section A, the diatomaceous earth filters for iron removal could be located at any one of four places, However, since the previous tables show that the location of the filters, except at the existing plant site, makes little difference to the yearly cost, only one table of estimated costs is given below. The possibility of locating the iron removal facilities at the existing treatment plant is also not considered, as this cost was found to be considerably higher.

TABLE 15

ESTIMATED CAPITAL COSTS OF INFILTRATION GALLERIES WITHOUT IRON REMOVAL

	1971 flows	1981 flows
Galleries & housings	$35,000	$18,000
Pumps	36,000	18,000
Electrical	9,600	3,400
Site piping	3,400	1,700
Control system	4,500	
Supply line	266,000	
Booster station		41,000
	$354,500	$82,100
Cost/yr @ 6% loan for 20 yrs.	30,800	7,100

TABLE 16

YEARLY OPERATING COSTS OF INFILTRATION GALLERIES WITHOUT IRON REMOVAL.

	1962-66	1967-71	1972-76	1977-81
Population	9,300	11,200	13,600	16,500
Consumption	160 Mil. Gal.	210 Mil. gal.	275 Mil. gal.	365 Mil. gal.
Pumping head	800 ft.	875 ft.	975 ft.	1100 ft.
Maintenance & Improvements	1,200	1,200	1,700	1,700
Chemicals	600	800	1,100	1,400
Power	14,500	21,000	31,000	47,000
Heat & light	500	500	1,200	1,200
Wages	6,000	6,500	8,000	8,000
Capital costs (from Table 15)	30,800	30,800	37,900	37,900
Existing capital cost	7,350	7,350	7,350	Nil
TOTAL	60,950	68,150	88,250	97,200
Cost/1000 gals.	0.38	0.325	0.32	0.27

4. No Treatment Required

In the event that the iron content of the water could be removed by natural filtration through the river gravels, the iron removal facilities would not be required. The estimated costs for this possibility are given below in Tables 17 and 18.

TABLE 17

ESTIMATED CAPITAL COSTS OF INFILTRATION GALLERIES WITH IRON REMOVAL

	1971 flows	1981 flows
Galleries & housings	$34,000	$18,000
Pumps	11,000	5,700
Electrical	7,500	2,300
Site piping	4,500	1,700
Control system	4,500	
Filter housing	6,800	
Filter mech. & elect.	32,000	16,000
Booster pumps & elect.	24,000	18,000
Supply line	266,000	
Booster station		41,000
	390,300	102,700
Cost/yr. @ 6% loan for 20 yrs.	34,000	8,900

TABLE 18

YEARLY OPERATING COSTS OF INFILTRATION GALLERIES WITH IRON REMOVAL

	1962-66	1967-71	1972-76	1977-81
Population	9,300	11,200	13,600	16,500
Consumption	160 mil.gal.	210 mil.gal.	275 mil.gal.	365 mil.gal.
Pumping head	800 ft.	875 ft.	975 ft.	1100 ft.
Maintenance & Improvements	$ 1,500	1,500	2,000	2,000
Chemicals	2,400	3,100	3,900	5,100
Power	15,200	21,900	32,600	49,000
Heat & Light	800	800	1,500	1,500
Wages	6,000	6,500	8,000	8,000
Capital Costs (from Table 17)	34,000	34,000	38,700	38,700
Fxisting capital cost	7,350	7,350	7,350	Nil
TOTAL	67,250	75,150	98,050	108,500
Cost/1000 gal.	0.42	0.36	0.36	0.30

C. Use of a River Intake

If water is taken directly out of the river by means of an intake, complete treatment of the water will be required to remove the turbidity and color. The most economical method of doing this would be to transport the raw water directly to the existing treatment plant, rather than build a new plant somewhere along the supply line route.

Since a properly designed river intake is very expensive itself and also since the extra 9,000 feet of supply line would be required to get the water from the south edge of Town to the plant, as well as increasing the capacity of the plant, it is apparent that this would be a more costly method of obtaining an increased water supply. This alternative will therefore not be considered further.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

A. Cost Summary

A summary table of expected yearly costs is given below for the five main alternatives considered in detail. Annual capital and operating costs, as well as the estimated unit costs of water are shown for each five year period from 1961 to 1981. The annual capital costs are based on twenty year debentures at six per cent interest. The unit costs of water represent the expected cost of the water delivered to the distribution system at system pressure. For comparison purposes, the 1960 costs of water are also presented.

COST COMPARISON TABLE

Alternative	Item	1960	1962-66	1967-71	1972-76	1977-81
Expansion of Existing Facilities	Cap.Cost/yr.	$ 7,350	$25,550*	$25,550*	$29,750*	$22,400
	Op. Cost/yr.	34,660	34,700	40,900	49,200	60,400
	Total	42,010	60,250	66,450	78,950	82,800
	Cost/1000 gal.	$ 0.36	$0.375	$0.315	$ 0.29	$0.225
Wells at the river with diatomite filters for iron removal	Cap. Cost/yr.		$41,350*	$41,350*	$50,750*	$43,400
	Op. Cost/yr.		25,900	33,800	48,000	65,600
	Total		67,250	75,150	98,750	109,000
	Cost/1000 gal.		$ 0.42	$ 0.36	$ 0.36	$ 0.30
Wells at the river with aeration and sandfilters for iron removal	Cap. Cost/yr.		$46,250*	$46,250*	$58,450*	$51,100
	Op. Cost/yr.		24,200	31,600	45,300	62,000
	Total		70,450	77,850	103,750	113,100
	Cost/1000 gal.		$ 0.43	$ 0.37	$ 0.38	$ 0.31

COST COMPARISON TABLE - Cont'd.

Alternative	Item	1960	1962-66	1967-71	1972-76	1977-81
Infiltration galleries with no iron removal	Cap. Cost/yr		$38,150*	$38,150*	$42,250*	$37,900
	Op. Cost/yr.		22,800	30,000	43,000	59,300
	Total		60,950	68,150	88,250	97,200
	Cost/1000 gal.		0.38	0.325	0.32	0.27
Infiltration galleries with diatomite filters for iron removal	Cap. Cost/yr		41,350*	41,350*	46,050*	38,700
	Op. Cost/yr		25,900	33,800	52,200	69,800
	Total		67,250	75,150	98,250	108,500
	Cost/1000 gal.		0.42	0.36	0.36	0.30

* $7,350 of existing capital costs per year included in these items.

The above table does not include cost figures for each possible site of the iron removal facilities, as it was found that very nearly the same yearly costs was involved in each case. The choice of location is therefore one of convenience. Iron removal facilities at the existing treatment plant are also not included, as the added cost of this site use gave no extra advantages in return.

Figures shown in the table indicate that during the first five-year period, an increase of seven cents per thousand gallons above present cost of water could be expected, if the most expensive alternative was constructed. If this increase was passed on to the consumers, it would cost a residential customer, who uses 3,000 gallons per month, an extra 21 cents per month.

It therefore becomes apparent that because of the relatively small variations in total yearly costs between the alternatives, the selection of the best method of water supply becomes just as much dependent upon other benefits derived, as upon economics.

After consideration of the various alternatives, it has been concluded that the City of Grande Prairie should accept the use of infiltration galleries at the Wapiti River as a tentative answer to the water supply needs of the City, for the following reasons:

1. When calculating the power costs for the long supply line alternatives, a unit cost of 2.2 cents per KWH was assumed, after preliminary talks with Canadian Utilities Ltd. This leads to annual power costs of from $15,000 in the period 1962-1966, to $49,000 in the period 1977-1981. If this rate could be reduced to say 1.5 cents per KWH, which we feel is quite possible, the yearly power costs would be reduced 30 percent, thus bringing the total yearly costs utilizing infiltration galleries without iron removal to a lower figure than the alternative of increasing the existing treatment plant.

2. Even if it is found that iron removal is required for the water obtained from the galleries, the cost per thousand gallons would only be 2 to 3 cents higher than that involved in expanding the existing plant, provided the power rate reduction can be obtained. It is felt that the added security of having the existing treatment plant left as an emergency source of supply is worth the slight additional cost. This stand-by source could prove very valuable if a sudden increase in growth and water consumption in Grande Prairie occurred, as it could postpone another major capital expenditure for a period of up to five or six years.

3. When looking further into the future than the expected 1981 flows, it can be seen that the existing treatment plant, if expanded now, would have to be expanded again when this consumption is reached. The supply from the Wapiti River, could however, be supplemented by the existing plant, as mentioned previously, or more water could be obtained through the proposed 10 inch diameter supply line by adding another booster station. This latter method would be particularly attractive if the power rates decreased.

4. Although water quality might rule out the use of shallow wells in the gravel terraces, because of the high hardness content which would not be filtered out by the iron removal equipment, the infiltration galleries can be expected to give water of about the same hardness as the river. This water which has an average (by weight) hardness of 160 parts per million, compares quite favorably with the present treated water of about 125 parts per million hardness.

5. The use of water from the Wapiti River would provide an alternate water resource, and establish the right of the City of Grande Prairie to use this source.

Because of the points which still require some clarification, as indicated above, it is recommended that the following immediate course of action be taken by the City.

1. That negotiations be started with the power company,

Canadian Utilities Ltd., to determine how low a power rate can be obtained for this particular project.

2. That possible methods of obtaining water from the Wapiti River by induced infiltration be explored. These might include the Ranney Method, which is essentially a patented infiltration gallery, or a perforated intake pipe installed a few feet below the river bed.

APPENDIX I

EXCERPTS FROM NOVEMBER 1957
INTERIM DATA REPORT

PRELIMINARY REPORT ON SURFACE WATER RESOURCES

OF

CITY OF GRANDE PRAIRIE

STAGE I

COMPILATION AND ANALYSIS OF BASIC DATA

STANLEY, GRIMBLE, ROBLIN LTD.
CONSULTING ENGINEERS
MUNICIPAL - STRUCTURAL - INDUSTRIAL
EDMONTON - CALGARY - SASKATOON - PENTICTON - VANCOUVER

D. R. STANLEY
B.SC., S.M., S.D., P.ENG.
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B.SC., M.SC., P.ENG.
H. L. ROBLIN
B.A.SC., P.ENG.

8908 - 99 STREET
EDMONTON, ALBERTA
TELEPHONE GENEVA 9-3907

November 18, 1957

LETTER OF TRANSMITTAL

Mayor and Council,
City of Grande Prairie,
Grande Prairie, Alberta.

Re: Water Resources - City of Grande Prairie

Dear Sirs:

As authorized by the City Engineer in his letter of March 16, 1957, we have undertaken a study of the water resources for the City of Grande Prairie.

The report contained herein is Phase 1 of the study, and includes the compilation and analyses of available hydrometric data and a list of additional information which is required in order to complete the study.

A very cursory field survey was carried out by our Mr. John A. Kerr, who also compiled all the available data and made the analyses.

As instructed by the Town Manager, Mr. John V. Meyer, in a letter of November 14, we are submitting the Stage 1 of the report, and will await further instructions before proceeding to complete the study.

Respectfully submitted,

STANLEY, GRIMBLE, ROBLIN LTD.

D. R. Stanley, P. Eng.

DRS/zp

TABLE OF CONTENTS

LIST OF APPENDICES

SYNOPSIS

In a letter dated March 16, 1957, the Town (now City) of Grande Prairie asked the firm of Stanley, Grimble, Roblin Limited, Consulting Engineers, to commence a study of surface water resources of the area around Grande Prairie for their own purpose, as well as a guide to industries which may wish to locate there in the future.

This report contains phase one of the study which is the compilation and analysis of basic data, the formation of tentative hypotheses, and the listing of information to be gathered in the field.

Phase two will be concerned with the gathering and analysis of field information, the testing and revision of the hypotheses of stage one, the formation of new hypotheses, and the laying out of construction schemes.

Only meagre hydrometric data is avilable. This data is given in Appendix 1. Because of this fact, meteorological data was used to calculate evaporation and as a basis for a statistical analysis of precipitation, evaporation, and evaporation minus precipitation. The results of this statistical analysis are presented in this report. Table 11 and Figure 10 summarize the calculations for the dryest year in twenty, presenting the net runoff as a function of K, the ratio of annual runoff from the land area to the annual precipitation on the land area. The value of K will be estimated by statistically analyzing its value for adjacent, similar drainage areas and from values given in technical literature. This will be done at a later date.

I. GENERAL DESCRIPTION

Location and general plans of the area are shown on Figures 1 and 2.

The following information was obtained from the economic survey of the Town of Grande Prairie prepared by the Department of Fconomic Affairs, Industrial Development Board, Government of the Province of Alberta in 1949.

Location

Section 23-71-6-W6, in Census Division No. 16. This location is 247 miles northwest of Edmonton; 370 miles on Highway No. 2 (and connections); 407 miles on the Northern Alberta Railway.

Altitude

2,193 at the airport.

Temperature

Mean annual temperature - 35.93°F.

Highest monthly mean (July) - 60.07°F.

Lowest monthly mean (January) - 9.40°F.

Average frost free days per year - 119 days

These data for period 1916 - 1947, inclusive.

Rainfall

Mean annual rainfall	- 10.46 inches
Mean annual snow fall	- 69.14 inches
Total average precipitation	- 17.36 inches

Geology

The bedrock underlying the glacial drift at Grande Prairie is of the Edmonton formation which is Upper Cretaceous in age. This horizon is a series of sandy shales and loose to well-consolidated sandstone. Coal is mined from this horizon in many areas.

Soil

Profile: - The soils vary from about 12 inches of black surface to those that have a strongly leached light color (grey) practically to the surface. The black soils, often of a silty nature, are usually found in the valleys and part way up the slopes. The grey soils are found at higher elevation.

Typical of this district are large areas of soil with a loose surface layer overlying an impervious sub-surface. A light grey layer usually divides these two layers. This soil is quite vulnerable to wind and water erosion.

Lime is found at depths of from 30 to 40 inches.

Fertility:- Extensive tests are being carried out by the Dominion Experimental Station at Beaverlodge. As yet not definite analysis has been concluded. The area has produced consistent yields of good quality cereals. In this respect the low evaporation rate has aided considerably.

Vegetation:- The area varies from "parkland" country to quite heavily wooded areas. The tree growth is generally denser with more evergreens than in black zones.

Land Use:- Good yields of wheat have been obtained on the black and dark colored soils. Mixed farming on the grey soils is the general practice with a system including legumes and fertilizer giving the best results. With adequate rotations, coarse grains give good results. This district is noted for championship crops.

History

The Christmas dinner of 1907 was attended by the eleven white residents of the district.

With the promise of rail connections, a rush of immigration began in 1910 - 1911.

Grande Prairie was incorporated as a village April 30, 1914, and with the arrival of the Edmonton, Dunvegan and British Columbia Railroad in 1916, rapidly progressed to incorporation as a town March 27, 1919. (Grande Prairie became a city in 1957).

Water

Water is obtained from a 210 million gallon reservoir on Bear Creek 1/4 miles N.W. of the town. The water is delivered to sedimentation basins and filters, then pumped to an elevated storage tank that connects with the distribution system.

Formerly five wells were used for the water supply. Two of these have been retained for emergency purposes and fill a concrete reservoir from which water can be pumped into the distribution system.

The total sedimentation basin capacity is 40,000 gallons. The clear water basin capacity is 2,200 gallons. Concrete construction is used throughout.

Delivery from the sedimentation basins to the filters is performed by two centrifugal pumps, one rated 54 g.p.m.; the other rated at 112 g.p.m. Both pumps are driven by electric motors. Delivery to the distribution system and elevated tank is performed by two centrifugal pumps, one rated at 108 g.p.m; the other rated at 54 g.p.m. Both pumps are driven by electric motors.

The concrete reservoir has a capacity of 100,000 gallons which is constantly maintained for fire purposes.

An additional pumping station has been installed containing two centrifugal pumps, each rated at 250 g.p.m. against a head of 132 feet. The pumps are driven by electric motors. The elevated tank has a capacity of 60,000 gallons.

Reserve Well No. 2 is 402 feet deep and has a yield of 17,280 gallons per day. It is operated by an electrically driven pump with a 12 g.p.m. capacity.

Reserve Well No. 4 is 187 feet deep and has a yield of 21,600 gallons per day. It is operated by an electrically driven pump with a 24 g.p.m. capacity.

The present consumption is 55,000 g.p.d. The domestic rate is $0.10 per 100 gallons. There are 139 domestic service connections, 61 commercial, 5 industrial, 10 institutional, and 24 hydrants.

A water analysis report in 1949 showed 182 p.p.m. total solids, 60 p.p.m. ignition loss, 90 p.p.m. hardness, 50 p.p.m. sulphates, 3 p.p.m. chlorides, and 60 p.p.m. alkalinity. The nature of the alkalinity is carbonate of lime and magnesia. There is a trace of iron.

<u>Industry</u>

There are choice industrial sites with adjacent trackage and highway facilities.

Grande Prairie can provide opportunity and good living conditions for any industry that can use the district resources or provide service for the trading area.

The trading area is bounded on the north by the Peace River, on the south by the end of settlement, about township 68, on the west by Hythe, and on the east by Sturgeon Lake. The trading area population is 17,432, according to the 1946 census.

Population

1907	- 11 white people
1946 census	- 2,267 (17,432 in trading area)
1949 estimate	- 3,600

(Figure 11 shows past and predicted population and water consumption figures)

II. STATISTICAL ANALYSIS OF METEOROLOGICAL DATA

Basic Climatological Data is given in Tables 1 to 4, inclusive

Table 5 shows the calculation of monthly evaporation for a period of thirteen years. The method of calculation used was that proposed in "Evaporation from Lakes and Reservoirs on the Canadian Prairies", Prairie Provinces Water Board, 1952. Evaporation is a function of vapor pressures (which are functions of temperature), wind velocity, and elevation. The Meyer formula which is used to obtain the evaporation quantitatively is:

$$E = C(V_w - V_a)(1 + 0.1W)(1 + 0.00001A)$$

where

E = Total monthly evaporation in inches of depth

V_w = Saturated vapor pressure in inches of mercury (obtained from tables as a function of temperature)

V_a = Actual vapor pressure at 25-foot height in inches of mercury (Saturated vapor pressure multiplied by relative humidity)

W = Mean monthly wind velocity at 25-foot height in miles per hour

A = Elevation in feet

The elevation of Bear Lake, 2,177, was used in the calculations, as it is the central and most important body of water. For other elevations, the evaporation would be multiplied by the ratio of elevation corrections. The variations of this ratio from 1.0 would be negligible for the area under consideration.

The results of the calculation are summarized in Table 6. Annual evaporation, precipitation, and evaporation minus precipitation figures for the thirteen years of record were then plotted as frequency curves from Table 7 to obtain the annual precipitation and the annual evaporation minus precipitation during the dryest year in twenty. Figures 3 to 9, inclusive are directly or indirectly related to the above calculations. These figures were used to calculate the net annual runnoff for various ratios of annual runoff from land area to annual precipitation on land area, as shown in Tables 8 to 11, inclusive. The results of the latter calculation are shown in Table 11 and on Figure 10.

APPENDICES

APPENDIX 1

HYDROMETRIC DATA

Bear River at Grande Prairie

The only discharge measurement published for public use was that made on May 9, 1917, at the town of Grande Prairie (N.W. 23-71-6-6). The width was 46.0 feet, the cross-sectional area 1,350 square feet, the mean velocity 0.76 feet per second, and discharge 102.0 cubic feet per second.

Wapiti River Near Grande Prairie

The only discharge measurements published for public use were several made in 1917 and 1918, 14 miles southeast of Grande Prairie. Stage records were kept from December 24, 1917, to March 31, 1918. The gauge zero was 88.00.

At the point where the discharge was measured, the banks were high, rocky and wooded, not liable to overflows, while the bed was sandy with small gravel, liable to shift, with two channels in early winter and one early in summer.

The maximum discharge and stage occurred on January 6, 1918, and were 1,375 cubic feet per second and 7.80 feet (elevation 95.80) respectively. Also note stage of 6.92 feet (elevation 94.92).

The minimum discharge and stage occurred on March 17, 1918, and were 261 cubic feet per second and 7.13 (elevation 95.13), respectively.

Discharge measurements were made from the ice with a current-meter. The stage-discharge relation was affected by ice conditions during winter months.

The following tables give further data:

Date	Discharge			Runoff
	Max.	Min.	Mean	Total in Acre-Feet
Dec. 24-31, 1917	916	765	834	132
Jan., 1918	1,375	481	728	44,763
Feb., 1918	499	598	453	25,158
Mar., 1918	405	261	321	19,738
				89,791

Date	Width	Cross Sectional Area	Mean Velocity	Gauge Rdg.	Water Elevation	Discharge
Dec 14/17	214	534	1.72	7.05	95.05	916a
Feb. 9/18	209	264	1.79	6.92	94.92	473a
Mar. 18/18		208	227	1.17	95.16	266a

a - Ice Conditions

TABLES

TABLE 1

BASIC CLIMATOLOGICAL DATA

OBTAINED FROM METEOROLOGICAL DIVISION OF DEPARTMENT OF TRANSPORT

1945 - DRYEST YEAR IN TWENTY

	Mean Monthly Temp.	Mean Monthly Relative Humidity	Mean Monthly Wind Velocity	Total Monthly Precipitation	Saturated Vapor Pressure
	Deg. F.	%	M.P.H.	Inches	Inches Hg.
Jan.	9.6	86.2	6.9	2.60	0.06954
Feb.	2.1	81.8	9.9	0.81	0.04938
March	25.4	75.8	9.8	0.35	0.13762
April	31.4	68.8	9.2	0.58	0.17605
May	50.0	52.5	9.6	1.67	0.36240
June	56.1	62.2	11.7	2.02	0.45340
July	61.4	56.8	11.0	0.68	0.54818
Aug.	62.0	54.5	9.2	0.39	0.55994
Sept.	49.1	70.0	11.2	1.12	0.35044
Oct.	40.1	73.2	12.2	1.04	0.24864
Nov.	6.2	94.5	6.4	1.23	0.05964
Dec.	5.3	96.5	4.6	0.76	0.05724
TOTAL				10.91	
AVERAGE					

TABLE 2

BASIC CLIMATOLOGICAL DATA FOR GRANDE PRAIRIE

OBTAINED FROM CLIMATOLOGICAL ATLAS OF NATIONAL RESEARCH COUNCIL

Temperature

Mean January Daily Temperature	+ 4°F
Mean January Daily Minimum Temperature	- 10°F
Mean January Daily Maximum Temperature	+ 13°F
Mean April Daily Temperature	36°F
Mean July Daily Temperature	60°F
Mean July Daily Minimum Temperature	45°F
Mean July Daily Maximum Temperature	75°F
Mean October Daily Temperature	37°F
Mean Annual Temperature	36° F
Mean Annual Minimum Temperature	- 38°F
Mean Annual Maximum Temperature	87°F
Extreme Lowest Recorded Temperature - 1921 - 50	- 60° to - 70°F
Extreme Highest Recorded Temperature - 1921 - 50	100°F
Winter Design Temperature (1%)	- 43°F
Winter Design Temperature (21/2%)	- 37°F
Winter Design Temperature (5%)	- 31°F
Winter Design Temperature (10%)	- 24°F
Summer Design Temperature (1%)	83°F
Summer Design Temperature (2 1/2%)	81°F
Summer Design Temperature (5%)	77°F
Summer Design Temperature (10%)	73°F
Mean Annual Total Degree-Days (65°F Base)	11,000

Humidity

Mean January Vapor Pressure	0.050"
Mean April Vapor Pressure	0.160"
Mean July Vapor Pressure	0.350"
Mean October Vapor Pressure	0.180"

Wind

Computed Maximum Gust Speed	90 MPH
Computed January Maximum Gust Speed	90 MPH
Computed April Maximum Gust Speed	73 MPH
Computed July Maximum Gust Speed	71 MPH
Computed October Maximum Gust Speed	82 MPH
Mean Winter Season Wind Speed	10 MPH
Mean Spring Season Wind Speed	10 MPH
Mean Summer Season Wind Speed	10 MPH
Mean Autumn Season Wind Speed	10 MPH

Direction Frequencies of Annual Winds - Greatest Percentage from West

Direction Frequencies of Winter Winds - Greatest Percentage from West, Northwest

Direction Frequencies of Summer Winds - Greatest Percentage from West

Table 2 (continued)

Snow

Maximum Recorded Depth of Snow on the Ground (1941-50)	39"
Computed Maximum Snow Load (horizontal surface)	39 lbs. per sq. ft.
Mean Annual Snowfall	65"
Mean October Snowfall	5"
Mean November Snowfall	10"
Mean December Snowfall	12-1/2"
Mean January Snowfall	12-1/2"
Mean Febraury Snowfall	10"
Mean March Snowfall	10"
Mean April Snowfall	5"
Mean Annual Number of Days with Measurable Snowfall	50

Precipitation

Mean Annual Total Precipitation	17"
Mean Annual Rainfall	10"
Mean Winter Season Rainfall	none
Mean Spring Season Rainfall	2"
Mean Summer Season Rainfall	6"
Mean Autumn Season Rainfall	2"
Mean Number of January Days with Total Precipitation of 0.1" or More	5
Mean Number of April Days with Total Precipitation of 0.1" or More	3
Mean Number of July Days with Total Precipitation of 0.1" or More	6
Mean Number of October Days with Total Precipitation of 0.1" or More	5
Maximum Precipitation in 24 Hours - 1921 - 50	5"
Fifteen-Minute Rainfall to be Expected once in 10 Years	0.65"

Sunshine and Insolation

Mean Annual Total Hours of Bright Sunshine	2,000
Mean January Total Hours of Bright Sunshine	75
Mean February Hours of Bright Sunshine	100
Mean March Total Hours of Bright Sunshine	150
Mean April Total Hours of Bright Sunshine	200
Mean May Total Hours of Bright Sunshine	250
Mean June Total Hours of Bright Sunshine	250
Mean July Total Hours of Bright Sunshine	280
Mean August Total Hours of Bright Sunshine	260
Mean September Total Hours of Bright Sunshine	175
Mean October Total Hours of Bright Sunshine	130
Mean November Total Hours of Bright Sunshine	70
Mean December Total Hours of Bright Sunshine	60
	2,000

TABLE 5

CALCULATION OF EVAPORATION

The Meyer Formula was used in the following calculations. It is

$$E = C (V_w - V_a) (1 + 0.1 W) (1 + 0.0001 A)$$

where

E = total monthly evaporation in inches of depth

Vw = saturated vapor pressure in inches of mercury

Va = actual vapor pressure at 25' height in inches of mercury

W = wind velocity at 25' height in miles per hour

A = elevation in feet.

NOTE: (1 + 0.00001 A) for A = 2177 is 1.022. For other elevations multiply evaporation figure by the ratio of elevation corrections.

Table 5 (continued)

	C	VwR	Va at 25'	Vw-Va at 25'	W at 25'	A	E
1945	Coef.	Inches Hg.	Inches Hg.	Inches Hg.	m.p.h.	Feet	Inches
Jan.	11.3	0.0600	0.0566	0.0129	5.1	2177	0.23
Feb.	11.3	0.0404	0.0381	0.0113	6.7	2177	0.22
Mar.	11.3	0.104	0.0981	0.0399	6.6	2177	0.77
April	11.3	0.121	0.114	0.062	6.4	2177	1.18
May	11.3	0.190	0.179	0.183	6.5	2177	3.50
June	11.3	0.282	0.266	0.187	8.0	2177	3.90
July	11.3	0.312	0.294	0.254	7.4	2177	5.13
Aug.	11.3	0.305	0.288	0.272	6.4	2177	5.18
Sept.	11.3	0.246	0.232	0.118	7.6	2177	2.42
Oct.	11.3	0.183	0.173	0.076	8.4	2177	1.62
Nov.	11.3	0.0563	0.0531	0.0065	4.8	2177	0.11
Dec.	11.3	0.0552	0.0521	0.0051	3.9	2177	0.08
Annual							24.34
Average							

April - October Mean V.P. = 0.234

Vapor Pressure Correction = 0.943

TABLE 6.

ANNUAL EVAPORATION, PRECIPITATION AND EVAPORATION MINUS PRECIPITATIC
IN CHRONOLOGICAL ORDER - 1943 to 1953 INCLUSIVE AND 1955 - 1956

Year	Annual Evaporation Inches	Annual Precipitation Inches	Annual Evaporation minus Precipitation Inches
1943	22.50	14.16	8.34
1944	24.57	17.61	6.96
1945	24.34	10.91	13.43
1946	22.59	11.98	10.61
1947	20.61	19.03	1.58
1948	18.76	22.29	minus 3.53
1949	20.82	15.63	5.19
1950	19.11	16.51	2.60
1951	16.68	18.98	minus 2.30
1952	19.36	15.50	3.80
1953	17.79	18.94	minus 1.15
1955	21.97	18.34	3.63
1956	22.99	17.65	5.34
TOTAL	272.09	217.53	54.50
AVERAGE	21.00	16.73	4.20

TABLE 8

DRAINAGE AREAS, LAND AREAS, AND WATER AREAS:

Description of Drainage Area:	Land Area	Water Area	Total Drainage Area
	Acres:	Acres:	Acres:
LaGlace Lake Above Outlet	99,400	3,000	102,400
Bear Lake Above Outlet	274,400	13,000	287,400
Grande Prairie Creek: Above Junction with Bear River	71,000	700	71,700

TABLE 9

RUNOFF FROM LAND AREAS DURING DRYEST YEAR IN 20 FOR VARIOUS VALUES OF K, RATIO OF ANNUAL RUNOFF FROM LAND AREA TO ANNUAL PRECIPITATION ON LAND AREA:

K	1:20 Annual Precipitation (Dryest Year in 20)	La Glace Lake Above Outlet		Bear Lake Above Outlet		Grande Prairie CK above Junction with Bear River	
		Land Area	Run-Off	Land Area	Run-Off	Land Area	Run-Off
RATIO	INCHES	Acres	Acre-Feet	Acres	Acre-Feet	Acres	Acre-Feet
0.1	11.0	99,400	9,100	274,400	25,100	71,000	6,500
0.2	"	"	18,200	"	50,200	"	13,000
0.3	"	"	27,300	"	75,300	"	19,500
0.4	"	"	36,400	"	100,400	"	26,000
0.5	"	"	45,000	"	126,000	"	32,500
0.6	"	"	54,600	"	150,600	"	39,000
0.7	"	"	63,700	"	175,100	"	45,500
0.8	"	"	72,800	"	200,800	"	52,000
0.9	"	"	81,900	"	225,900	"	58,500
1.0	"	"	91,000	"	251,000	"	65,000

TABLE 10

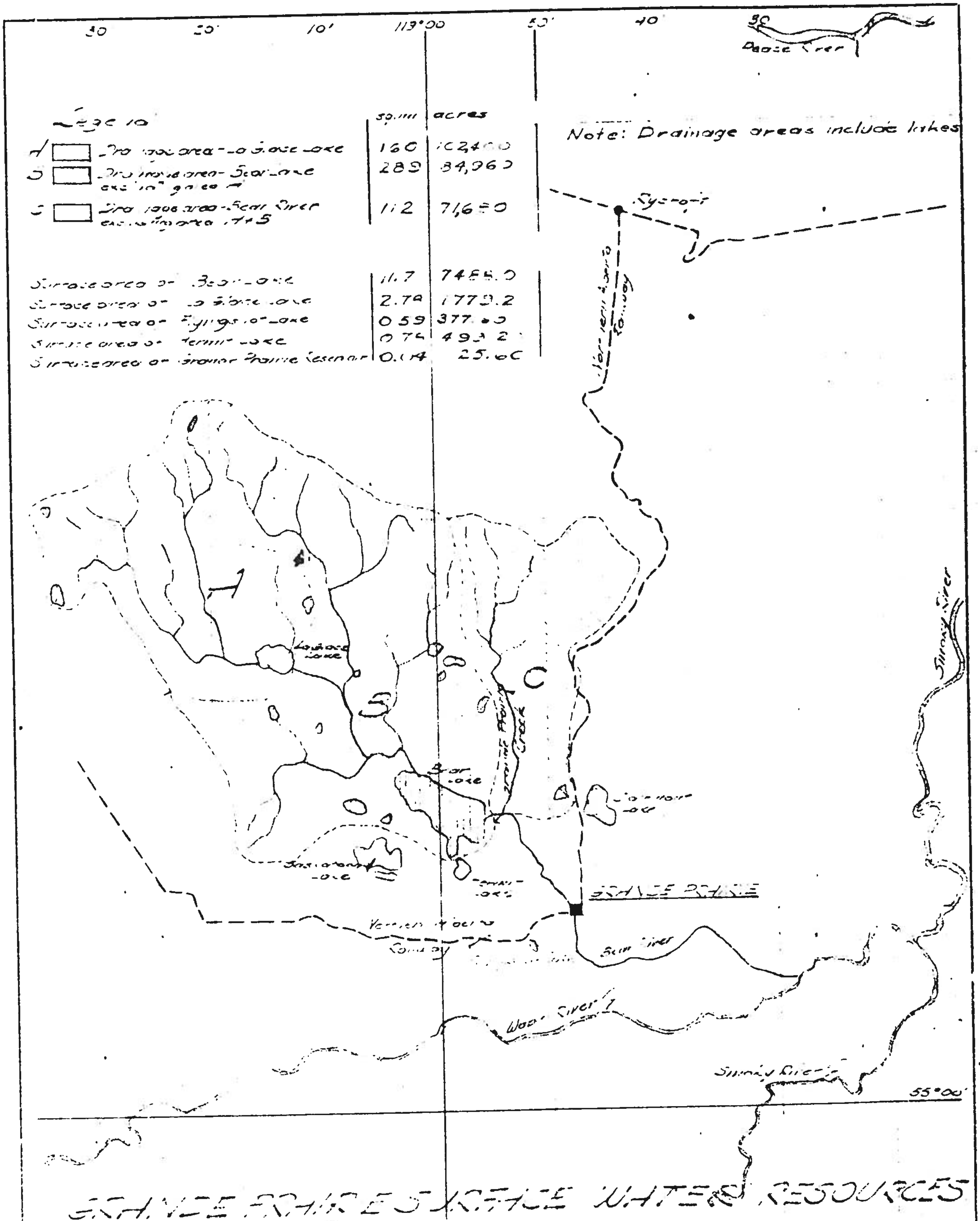
EVAPORATION MINUS PRECIPITATION FROM WATER AREAS DURING DRYEST YEAR IN 20:

Description of Drainage Area	Water Area 1:20	Evaporation Minus Precipitation (Dryest Year in 20)	
	Acres	Inches	Acre-Feet
La Glace Lake Above Outlet	3,000	17.0	4,200
Bear Lake Above Outlet	13,000	17.0	18,400
Grande Prairie Creek Above Junction with Bear River	700	17.0	1,000

TABLE 11

NET RUNOFF FROM DRAINAGE AREAS FURING DRYEST YEAR IN 20 FOR VARIOUS VALUES OF K, RATIO OF ANNUAL RUNOFF FROM LAND AREA TO ANNUAL PRECIPITATION ON LAND AREA.

K	La Glace Lake Above Outlet			Bear Lake Above Outlet			Grande Prairie Creek Above Junction with Bear River		
	Runoff From Land Area	Evap. Minus Prec.	Net Runoff From Water Area	Runoff From Land Area	Evap. Minus Run-off Prec. From Water Area	Net	Runoff From Land Area	Evap. Minus Prec. From Water Area	Net Run-off
	Acre-Feet	Acre Feet	Acre Feet	Acre Feet	Acre Feet	Acre Feet	Acre Feet	Acre Feet	Acre Feet
0	0	4,200	-4,200	0	18,400	-18,400	0	1,000	-1000
01	9,100	"	4,900	25,100	"	6,700	6500	"	5,500
0.2	18,200	"	14,000	50,200	"	31,800	13000	"	12,000
0.3	27,300	"	23,100	75,300	"	56,900	19500	"	18,500
0.4	36,400	"	32,200	100,400	"	82,000	26000	"	25,000
0.5	45,500	"	41,300	126,000	"	107,000	32500	"	31,500
0.6	54,600	"	50,400	150,600	"	132,200	39000	"	38,000
0.7	63,700	"	59,500	175,100	"	156,700	45500	"	44,500
0.8	72,800	"	68,600	200,800	"	182,400	52000	"	51,000
0.9	81,900	"	77,700	225,400	"	207,500	58500	"	57,500
1.0	91,000	"	86,800	251,000	"	232,600	65000	"	64,000



STANLEY, GRIMBLE, ROBLIN LTD. — CONSULTING ENGINEERS — EDMONTON

FIGURE I.

LOCATION PLAN

SHOWING DRAINAGE AREA

APPROVED:	DATE: JUNE 13 - 57	SCALE: 1" = 8 MILES	SHEET No.

APPENDIX II

TABLE OF WAPITI RIVER WATER ANALYSIS REPORTS

TABLE OF WATER ANALYSIS RESULTS FROM WAPITI RIVER SAMPLES

Date	Jan./59	Feb./59	Mar./59	Mar./59	Apr./59
Total Solids	204	204	204	238	162
Ignition Losses	80	80	82	54	34
Hardness	195	185	210	130	85
Sulphates	18	19	17	67	38
Chlorides	nil	nil	nil	nil	nil
Alkalinity	165	160	165	115	95
Nitrites	Traces	Traces	Traces	Traces	0.5
Nitrates	Traces	Traces	Traces	Traces	Traces
Iron	0.2	0.2	nil	0.2	0.7
Fluorine	-	-	-	-	-

TABLE OF WATER ANALYSIS RESULTS FROM WAPITI RIVER SAMPLES

Date	Dec./59	Jan./60	Feb./60	Mar./60	Sept./60	Oct./61
Total Solids	-	-	248	304	346	160
Ignition Losses	-	-	108	110	124	48
Hardness	133	164	200	160	230	125
Sulphates	15	20	16	59	32	27
Chlorides	1	1	nil	nil	3	1
Alkalinity	122	150	180	160	260	110
Nitrites	-	-	nil	nil	nil	nil
Nitrates	0.3	-	nil	nil	nil	nil
Iron	0.5	-	0.6	1	1.2	nil
Fluorine	-	-	-	-	-	-

APPENDIX III

TABLE OF WELL WATER ANALYSIS REPORTS

TABLE OF WATER ANALYSIS RESULTS FROM WELL SITE SAMPLES

Date	Oct./61	Oct./61	Oct./61	Oct./61
Total Solids	386	402	454	432
Ignition Losses	118	46	54	150
Hardness	305	275	305	295
Sulphates	20	71	86	17
Chlorides	2	1	1	1
Alkalinity	360	345	375	375
Nitrites	nil	Trace	nil	nil
Nitrates	nil	Trace	nil	nil
Iron	5/	5/	3/	5/
Fluorine	-	-	-	-

APPENDIX IV

TABLE OF RESERVOIR WATER ANALYSIS REPORTS

TABLE OF WATER ANALYSIS RESULTS FROM RESERVOIR SAMPLES

Date	Mar./59	Apr./59	Dec./59	Feb./60	Jan./60	Mar./60
Total Solids	286	172	-	258	-	310
Ignition Losses	108	52	-	82	-	86
Hardness	135	45	99	120	101	160
Sulphates	22	45	30	53	30	64
Chlorides	13	nil	1	2	1	nil
Alkalinity	175	60	101	130	106	180
Nitrites	Traces	Traces	-	Trace	-	Trace
Nitrates	Traces	1.4	1	0.3	-	0.6
Iron	0.8	1.2	0.6	0.6	-	2.0
Fluorine	-	-	-	-	-	-

APPENDIX V

TREATED WATER ANALYSIS REPORT

TABLE OF WATER ANALYSIS RESULTS FROM TREATED WATER SAMPLES

Date	October, 1959
Total Solids	-
Ignition Losses	-
Hardness	128
Sulphates	-
Chlorides	-
Alkalinity	106
Nitrites	-
Nitrates	-
Iron	-
Fluorine	-

APPENDIX VI

EXCERPTS FROM 1961 TEST DRILLING PROGRAMME RESULTS

RESEARCH COUNCIL OF ALBERTA

87th Avenue and 114th Street
Edmonton, Alberta, Canada.

Groundwater Division

November 20, 1961.

Mr. Wm. Oldham. P. Eng.,
Stanley, Grimble, Roblin Ltd.,
8908 - 99 Street,
EDMONTON, Alberta.

Dear Bill:

Re: Groundwater Test Program - Grande Prairie

Enclosed are copies of the data sheets for the Grande Prairie groundwater test program and a copy of the recent letter sent to F.W. Beairsto, P. Eng., City Engineer, outlining the initial results and recommendations.

If there are any further questions do not hesitate to call. All the best for now.

Yours very truly,

John F. Jones, P. Geol.,
Groundwater Geologist.

JFJ/G
encs.

Groundwater Division

November 10, 1961.

Mr. F.W. Beairsto, P. Eng.,
City Engineer,
City of Grande Prairie,
10102 - 99 Avenue,
GRANDE PRAIRIE, Alberta.

Dear Dick:

Re: Groundwater Test Program - Wapiti River
Approx. N. 1/2, Sec. 23, Tp. 70, R. 6, W. 6 M.

Examination of the pumping test data indicate that there is about a 50% well loss in the pumping well and that it has not been adequately developed to produce its maximum yield of water per foot of drawdown. As the aquifer is quite thin (16 - 17') this reduces the head in the pumping well considerably and its maximum yield cannot be obtained.

In addition, the pumping test data indicate that it was not carried out sufficiently long so that equilibrium was reached in the stabilization of the water levels in the pumping and observation wells. As a result, this makes it very difficult to evaluate with any great degree of precision the permeability of the aquifer materials. In addition, the river stage dropped about 0.83 of a foot during the test, which is reflected as a general lowering of the water levels in the pumping and observation wells as they are very close to the river in addition to the drawdown caused by pumping. Over an extended pumping test the local effect of the change in river stage could be accounted for.

However, estimates of the permeability of the aquifer materials, based on the initial drawdown measurements in the observation wells indicate an average permeability about 2400 gals. per square foot/day which is very good for a sand and gravel.

Mr. F. W. Beairsto, November 10, 1961.

Before any further work on new wells at this test site be done, I think that an accurate value of the permeability and an idea of the change in quality of the water with time should be sought. This would involve:

1) developing the present well by surging and bailing until the maximum yield of water per foot of drawdown is obtained.

2) an extended pumping test at a high rate, between 100 and 200 gallons per minute, until the water levels in the pumping and observation wells have stabilized for a considerable length of time.

3) regular sampling of the water that is discharged and testing it to see if there is a change of iron content with time, etc.

According to the literature which I have been looking up on the subject of induced infiltration, it sometimes takes a considerable length of time (i. e. several months) until the water quality in such an aquifer approaches and stays near that of the quality of the river water.

I feel that an extended pumping test (one month of longer) as outlined above, and water level measurements carried out in the same manner as the first pump test for the first two days and then daily measurements of the water level in the pumping and observation wells for the duration of the test, should be done. It would be especially worthwhile in view of the initial investment in the test site and the additional cost to do it would be small in comparison. I feel that the information obtained would answer many of the questions that remain "in the air" at the present time and would be one of the most economical ways in which to find them. Of course, this does not substitute for additional testing of a different nature that could go on during the same period.

Enclosed are copies of the pumping test data, water analyses, well logs, etc. requested by you.

I trust that this is satisfactory. Do not hesitate to get in touch with me if there are any further questions. All the best for now.

Yours very truly,

John F. Jones, P. Geol.,
Groundwater Geologist.

JFJ/G
encls.

Groundwater Test Data,
City of Grande Prairie - Wapiti River Test Site

Well Logs

Well	Log	
Pumping Well	0 - 17.0'	sand, silt and clay
	17.0-33.5'	sand and gravel
	33.5-	sandy shale (Wapiti Formation)
50' South	0 -17.0'	sand, silt and clay
	17.0-33.5'	sand and gravel
	33.5-43.0	silty sand
	43.0-	shale (Wapiti formation)
100' North	0 -17.0'	sand, silt and clay
	17.0-34.0	sand and gravel
	34.0-	shale (Wapiti formation)
100' West	0 -17.0'	sand, silt and clay
	17.0-33.0	sand and gravel
	33.0-35.0	shale (Wapiti formation)
100' East	0 -15.0'	sand, silt and clay
	15.0-33.0	sand and gravel
	33.0-35.0	sand
	35.0-	shale
500' East	0 -15.0'	sand, silt and clay
	15.0-33.0	sand and gravel
	33.0-34.0	silty sand

Observation wells - had the bottom 20' of the casing slotted and were subsequently developed with air. Approximately 33.0' of casing in each observation well.

Water Levels

1000 hours October 3, 1961

Well	100'N	50'S	100'W	100'E
Static level	16.80'	17.26'	18.26'	17.40'

1100 hours October 20, 1961

Well	Pumping	100'N	50'S	100'W	100'E	500'E
Static level	16.37' [1] 16.17' [2]	15.63'	15.52'	16.67'	15.74'	13.16'
Depth to well bottom		30.5'	24.0'	31.0'	25.5'	30.5'

1 = Elect. tape
2 = Steel tape

River Water Temperature

Date	Time	Temperature
20/10/61	1215 hrs.	35.5°F.
"	1540 hrs.	35.5°F.
"	2025 hrs.	33.5°F.
21/10/61	0830 hrs.	32.0°F.
"	1535 hrs.	32.0°F.

River Levels

Date	Time	Drop in level since 1100 hours 20/10/61
20/10/61	2320 hrs.	0.22'
21/10/61	0830 hrs.	0.45'
"	1535 hrs.	0.52'
23/10/61	0955 hrs.	0.83'

Iron Test of Water - Wapiti Pump Test

Well	Date	Time	Iron Content parts per million
Pumping	20/10/61	1645	7.5 +
	"	2040	7.5 +
	21/10/61	0805	7.5 +
		1530	7.5 +
	22/10/61	1020	7.5 +
	23/10/61	1000	7.5 +
50'S	23/10/61	1420	7.5 +
50'S	21/10/61	1330	7.5 +
100'N	"	1515	7.5 +
100'W	"	1515	7.5 +
100'E	21/10/61	1530	5.0 +
500'E	22/10/61	1025	7.5 +
50' S	23/11/61	1005	7.5 +
100'N	"	1010	7.5 +
100'W	"	1010	7.5 +
100'E	23/10/61	1020	5.0 +
500'E	23/10/61	1020	7.5 +
Boy Scout Spring	21/10/61		0.6
Dude Ranch	22/10/61		0.6
Hill Bottom Spring	21/10/61		1.5
River Water	20/10/61		0.6

Water Samples Submitted to Provincial Analyst

From Pumping Well

Sample	Date	Time
G.P. #1	20/1-/61	2030
G.P. #2	21/10/61	0825
G.P. #3	22/10/61	1245
G.P. #5	23/10/61	1130

From Wapiti River

G.P. #4	22/10/61	1780

See attached copies of chemical analyses

Well Locations and Relative Elevations, October 20, 1961.

Elevation of Wells - Top of Casing Marks

Well	Elev.
500' East	100.00'
100' East	102.70'
100' North	102.50'
Pumping Well	103.08'
50' South	102.51'
100' West	103.66'
River Level	86.96'

Corrected Distances between Wells and Wapiti River

Well	Distance from Edge of River Bank (located to south of well site)	Distance from Pumping Well
100' West	71.0'	100.00'
100' North	180.2'	107.60'
50' South	22.0'	50.60'
100' East	71.0'	99.60'
500' East	79.0'	499.60'

All measurements taken from centre of wells.

Well Location 100' North
Status: Observation
r: 107.60'

Pumping Test: Grande Prairie (Wapiti) Date: 20/10/61

Conducted by: G.M. Gabert

Date	Time	Static Water Level	Dept to Water	Remarks
20/10/61	1100	15.63		
	1300		15.63	Start Pumping Test
	1301		15.64	
	1302		15.64	Measurements made
	1303		15.65	With Steel Tape
	1304		15.68	
	1305		15.68	
	1306		15.71	
	1307		15.72	
	1308		15.75(5)	
	1309		15.78	
	1310		15.80	
	1315		15.97	
	1320		15.98	
	1325		15.99	
	1330		16.03	
	1335		16.07	
	1340		16.10	
	1345		16.125	
	1350		16.16	
	1355		16.18	
	1400		16.205	
	1410		16.25	
	1420		16.28	
	1430		16.33	
	1440		16.35(5)	
	1450		16.37	
	1500		16.41	
	1530		16.45	
	1600		16.54	
	1632		16.59	
	1702		16.64	
	1810		16.83	
	1904		16.87	
	2007		16.88	
	2108		16.94	
	2205		16.99	
	2310		17.05	
21/10/61	0007		17.05	
	0112		17.15	
	0208		17.17	
	0308		17.18	
	0408		17.25	
	0507		17.27	
	0607		17.28	
	0707		17.33	
	0802		17.33	
	0911		17.35	
	1009		17.36	
	1104		17.38	

Well Location 100' North
Status: Observation
r: 107.60

Pumping Test: Grande Prairie (Wapiti) Date: 20/10/61

Conducted by: G.M. Gabert

Date	Time	Static Water Level	Depth of Water	Remarks
21/10/61	1207		17.40	
	1307		17.42	
	1606		17.34	
	1915		17.51	
	2218		17.58	
	0115		17.54	
	0412		17.59	
	0708		17.75	
	1008		17.73	
	1306		17.78	
22/10/61	2112		17.83	
23/10/61	0515		17.90	
	1200		17.98	Stop Pumping Test

Well Location: 50' South | Pumping Test: Recovery | Date: 23/10/61

Status: Observation

r:

Conducted by: G.M. Gabert | Page: 1

Date	Time	Static Water Level	Depth to Water	Remarks
23/10/61	1200	15.52	18.50	
	1201		18.46	
	1202		18.40	
	1203		18.37	
	1204		18.31	
	1205		18.29	
	1206		18.27	
	1207		18.24	
	1208		18.22	
	1209		18.20	
	1210		18.18	
	1215		18.12	
	1220		18.06	
	1225		18.02	
	1230		17.98	
	1235		17.95	
	1240		17.92	
	1245		17.90	
	1250		17.87	
	1255		17.85	
	1300		17.84	
	1310		17.78	
	1320		17.75	
	1330		17.71	
	1340		17.68	
	1350		17.63	
	1400		17.60	
	1431		17.50	
	1501		17.40	
	1532		17.29	
	1600		17.20	
	1702		17.10	
	1803		16.98	
	1904		16.91	
	2004		16.85	
	2103		16.79	
	2205		16.75	
24/10/61	0003		16.67	
	0203		16.62	
	0403		16.59	
	0703		16.54	
	0903		16.54	

Well Location: Pumping Well
Status: Pumping Well Recovery
re:

Pumping Test: Grande Prairie (Wapiti) Date: 23/10/61

Conducted by: G. M. Gabert Page: 1

Date	Time	Static Water Level	Depth of Water	Remarks
23/10/61	1200	16.37	26.00	Stop Pumping Test Measurements made with an Electric Tape
	1201		21.45	
	1202		21.00	
	1203		20.84	
	1204		20.74	
	1205		20.63	
	1206		20.63	
	1207		20.61	
	1208		20.59	
	1209		20.55	
	1210		20.51	
	1215		20.35	
	1220		20.29	
	1225		20.20	
	1230		20.12	
	1235		20.04	
	1240		20.00	
	1245		19.94	
	1250		19.84	
	1255		19.77	
	1300		19.74	
	1310		19.63	
	1320		19.52	
	1330		19.42	
	1340		19.35	
	1350		19.26	
	1400		19.17	
	1430		19.01	
	1500		18.71	
	1530		18.51	
	1600		18.39	
	1700		18.18	
	1800		18.00	
	1900		17.86	
	2000		17.79	
	2100		17.71	
	2200		17.63	
	2400		17.54	
	0200		17.44	
	0400		17.39	
	0700		17.34	
	0900		17.30	Stop Recovery Measurements

Well Location: ____________________

Status: Pumping Well

r: o

Pumping Test: Grande Prairie (Wapiti)

Conducted by: G. M. Gabert

Date: 20/10/61

Page: 1 of 2

Date	Time	t Min.	Static Water Level	Depth to Water	Draw-down	Remarks
20/10/61	1100		16.37			Measured with Electric Tape
	1300	0				Start Pumping Test
	1301	1		19.85	3.48	45 gals/38 Sec 1317
	1302	2		20.38	4.01	
	1303	3		21.12	4.75	
	1304	4		21.85	5.48	
	1305	5		22.24	5.87	
	1306	6		22.43	6.06	
	1307	7		22.55	6.18	
	1308	8		22.68	6.31	
	1309	9		22.68	6.31	
	1310	10		22.68	6.31	
	1315	15		22.85	6.48	
	1320	20		22.80	6.43	
	1326	26		22.94	6.57	
	1331	31		23.09	6.72	
	1335	35		23.13	6.76	45 gals/38.5 Sec @ 1338
	1340	40		23.18	6.81	
	1345	45		23.22	6.85	
	1350	50		23.22	6.85	1352 - 39.5°F
	1355	55		23.22	6.85	
	1401	61		23.30	6.93	
	1410	70		23.32	6.95	
	1420	80		23.43	7.06	45 gals/38 Sec @ 1425
	1430	90		23.48	7.11	
	1440	100		23.53	7.16	
	1450	110		23.62	7.25	
	1500	120		23.62	7.25	
	1530	150		23.72	7.35	41°F
	1600	180		23.77	7.40	
	1630	210		23.90	7.53	
	1700	240		24.03	7.66	1710 45 gals /41 Sec
	1800	300		24.06	7.69	
	1900	360		24.25	7.86	2020 45 gals /41.5 Sec.
	2000	420		24.60	8.23	40°F.
	2100	480		24.63	8.26	
	2200	540		24.70	8.33	
	2300	600		24.60	8.23	2320 45 gals /41.5 Sec.
	2400	660		24.60	8.23	
21/10/61	0100	720		24.78	8.41	
	0200	780		24.85	8.48	
	0300	840		24.90	8.53	
	0400	900		24.76	8.39	
	0500	960		24.78	8.41	
	0600	1020		24.86	8.49	
	0700	1080		24.76	8.39	0820 40.5°F
	0800	1140		24.84	8.47	840 45 gal /45 Sec.
	0900	1200		24.68	8.31	
	1000	1260		24.71	8.34	
	1100	1320		24.59	8.22	

Well Location: Grande Prairie Pumping Test: 41 Date: 20/10/61
Status: Pumping Well
r: Conducted by: G.M. Gabert Page: 2 of 2

Date	Time	t Min.	Static Water Level	Depth to Water	Draw-down	Remarks
			16.37			
21/10/61	1200	1380		24.65	8.28	1220 45 gals /46 Sec.
	1300	1440		24.36	7.99	Increased speed of engine slightly
	1600	1620		25.30	8.93	1615 45 gals /43 Sec.
	1907	1807		24.95	8.58	
	2210	1990		25.30	8.93	
22/10/61	0105	2165		25.43	9.06	
	0400	2340		25.50	9.13	
	0700	2520		25.70	9.33	
	1000	2800		25.38	9.01	1030 42°F
	1300	2880		25.75	9.38	1135 45 gals /46 Sec.
	2100	3360		25.69	9.32	1800 38 Sec / 45 gals
23/10/61	0500	3840		26.23	9.86	1000 41.5°F.
	1200	4260		26.00	9.63	1105 45 gals /47 Sec Stop Pumping Test 1200 Total of 71 hours of Pumping

APPENDIX VII

EXCERPTS FROM 1960 TEST DRILLING PROGRAMME RESULTS

THE GROUNDWATER POTENTIAL OF ALLUVIAL TERRACES, ALONG THE WAPITI RIVER, SOUTH OF GRANDE PRAIRIE, ALBERTA

J.F. Jones,
Groundwater Division,
Research Council of Alberta

October, 1960

Index

THE GROUNDWATER POTENTIAL OF ALLUVIAL TERRACES, ALONG THE WAPITI RIVER, SOUTH OF GRANDE PRAIRIE, ALBERTA

Introduction

This report deals in part with information obtained from groundwater investigations carried out by the Research Council of Alberta during the summer of 1960, of a general study to evaluate:

1. The groundwater potential of possible alluvial terrace aquifers, along the major drainage ways in the Peace River district.

2. The relationship between river flow and groundwater recharge or discharge of alluvial terraces. For this purpose, observation wells were established.

3. Hydrologic methods and best method of approach in solving for aquifer coefficients in unconfined aquifers adjacent to perennial streams.

4. The drilling techniques and well completion practices in sand and gravel alluvial terraces.

The information contained below is from the Research Council of Alberta Test Site #1, Wapiti River, Grovedale Bridge, south of Grande Prairie, Alberta. It is hoped that this data will aid in evaluating the groundwater potential in this area.

Location and Description of Area Tested

R.C.A. test site #1 is located on a recent alluvial terrace on the south side of the Wapiti River (centre south side Sec. 23, Tp. 70, R. 6, W. 6th Mer.). The test site is approximately 7 miles south of the centre of the City of Grande Prairie, Alberta (N.W. cor. Sec. 24, Tp. 71, R. 6, W.6th Mer.). The site was quite accessible as a small camping park had been recently established, and access roads were provided.

In order to establish the geologic and hydrologic conditions of the terraces, 4 test holes were drilled with a rotary drilling rig by Independent Drilling and Exploration Co. Ltd. of Edmonton.

The alluvial terrace at this locality consisted of a surface covering of sand, silt and clay which overlaid approximately 15 feet of water-saturated coarse gravels. A pumping test site was established here.

See attached sketch for pump test site location and layout.

See appendix for test hole logs.

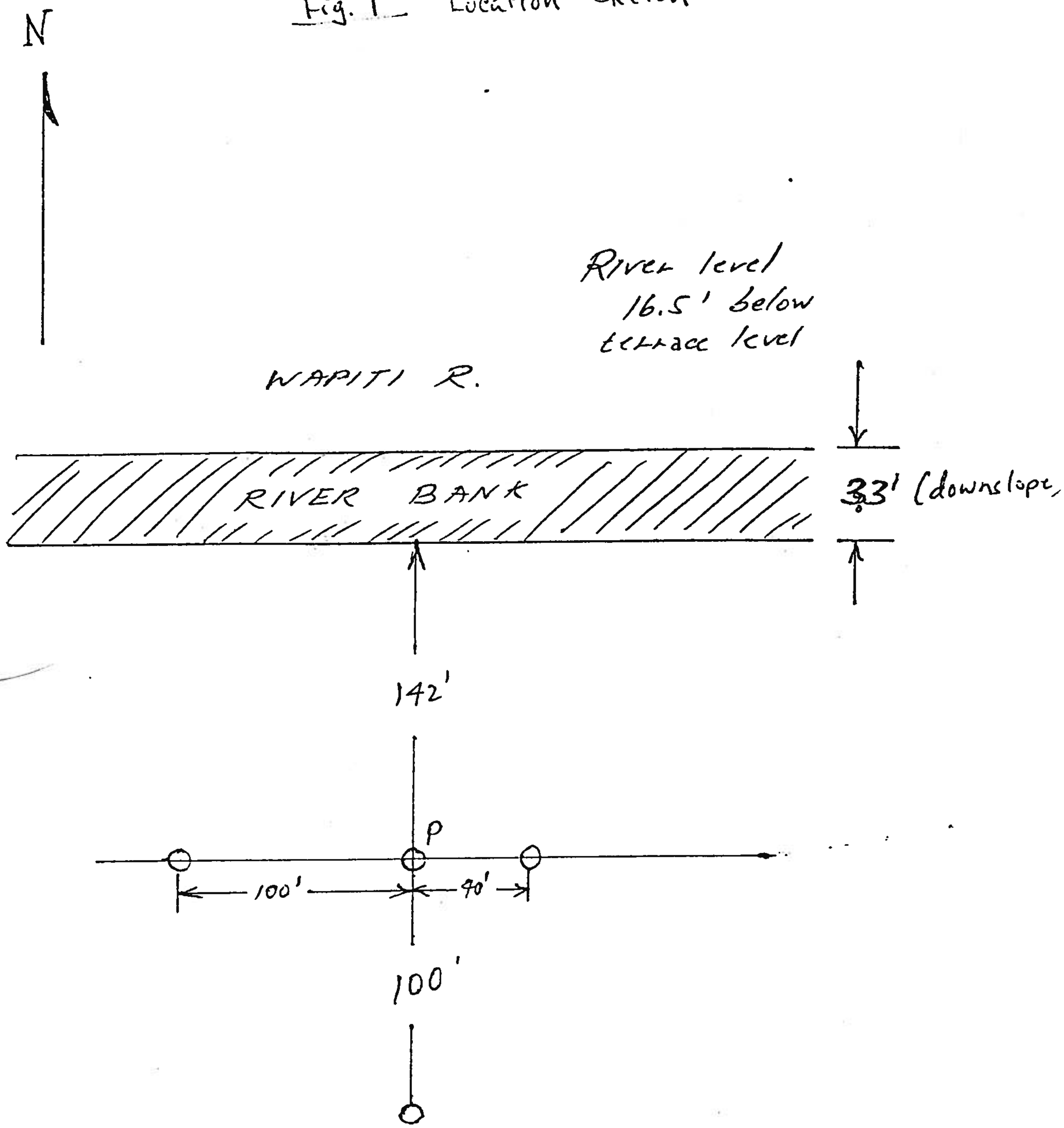
Pump Test Results

General Statement:

For test purposes a test pump (Pomona little Chief) was installed in a well with 4 1/4" I.D. black insert joint water well casing. The casing was slotted the saturated length of the aquifer with 1/4" slots. The pumping test was run for 26 hours at a rate of 70 gallons per minute August 20 and 21, 1960. Water-level measurements were made with a steel tape of both drawdown and recovery in observation wells spaced around the pumping well (see attached sketch, Fig. 1). The water from the pumping well was discharged through pipe to the Wapiti River.

Three water samples were taken of the pumping well during the test. Temperature measurements were made on both the well and Wapiti River waters. See section on water quality.

Fig. 1 Location Sketch



Copied from JTJ's original sketch.
DJR.

AQUIFER COEFFICIENTS AND HYDROLOGIC BOUNDARIES

The following aquifer coefficients were to be determined.

T, The coefficient of transmissibility of an aquifer is defined as the rate of flow of water in gallons per day which passes through a vertical strip of an aquifer one foot wide, with a unit hydraulic gradient. Stated in another way, the transmissibility is the product of the thickness, m, and the permeability, p, of the aquifer.

S, The coefficient of storage may be defined as the amount of water, in cubic feet, that will be released from storage in each vertical column of an aquifer with a height equal to the thickness of the saturated portion of the aquifer and a base one foot square when the hydrostatic head is lowered one foot.

Transmissibility Determination by standard methods

Obs. Well, 40' east

T = 38,200 gals/ft/day - Theis method
T = 41,000 gals/ft/day - Jacob method

Obs. Well, 100' west

T = 44,500 gals/ft/day - Theis method
T = 46,000 gals/ft/day - Jacob method

Obs. Well, 100' south

T = 44,500 gals/ft/day - Theis method
T = 68,400 gals/ft/day - Jacob method

Average T, Theis = 42,400 gals/ft/day

Average T, Jacob = 51,800 gals/ft/day

Average T, both methods = 47,100 gals/ft/day

The average T for both methods was used in all calculations

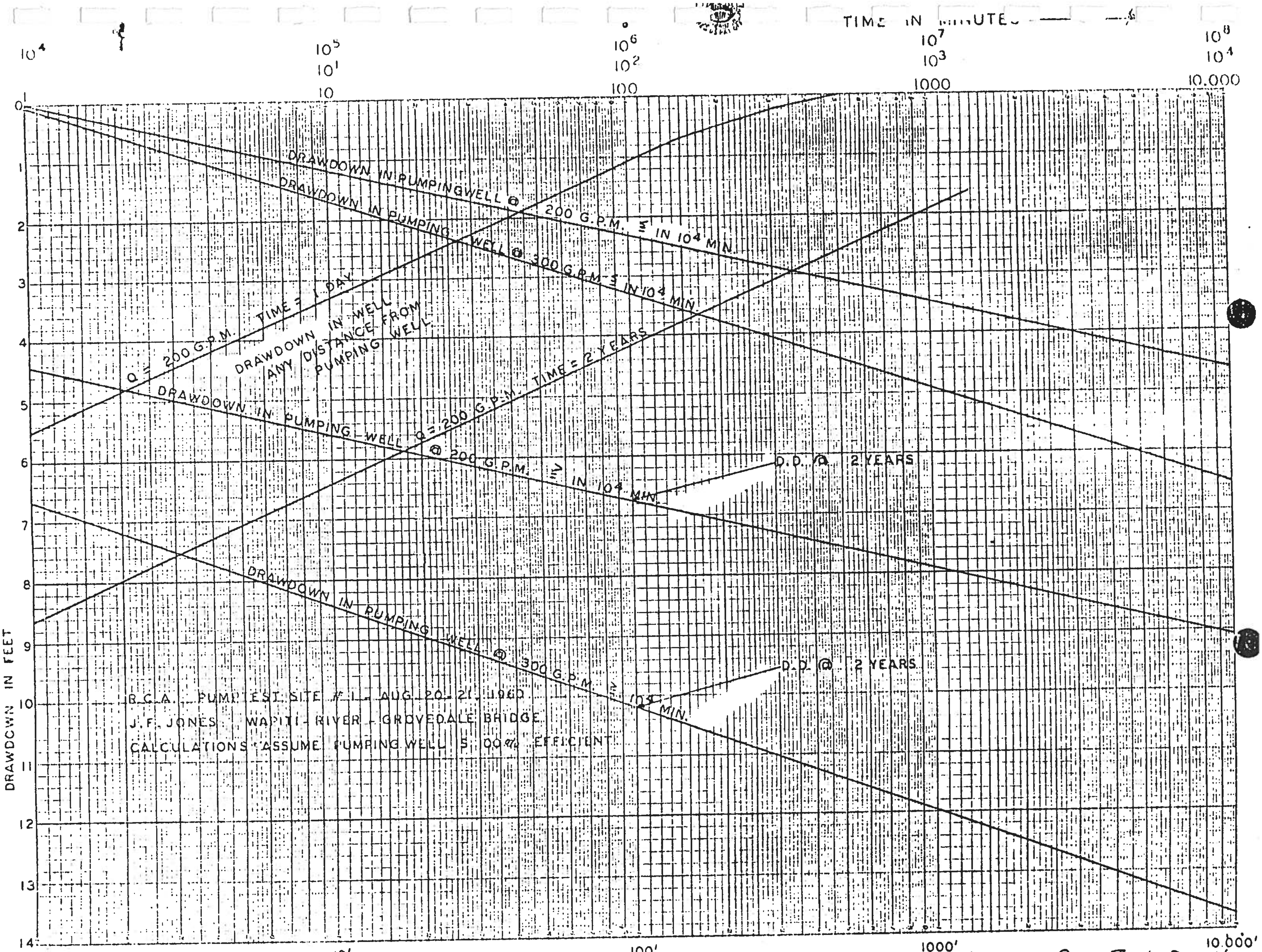
Since T = Pm T = 47,100 gals/ft/day

m = 15' P = 3,140 gals/ft^2/day

P = Permeability (average)

Permeability determined from the Dupuit free Aquifer equation:

P = 3,420 gals/ft^2/day, which compares very closely
T = 51,300 gals/ft/ day which is slightly higher by this method.



Graphical Presentation of Pump Test Results

Storage Coefficient

The storage coefficient varies considerably with time, especially in the early stages of the pumping test, but in the case of unconfined aquifers such as the alluvial terraces, as time increases the storage coefficient eventually equals the specific yield.

Specific yield for coarse gravels

20% $\therefore$ S = .20

This value is used to replace S (storage coefficient) in all calculations.

The saturated thickness (m) of the gravels was approximately 15.0' on August 17, 1960.

The values for both the transmissibility and storage coefficient can be considered to be very good. Based on these values predictions can be made about the performance of an aquifer.

Drawdown and Interference Calculations for estimations of future water levels

In determining the drawdown in and near a pumping well the following equations are used:

$$s = \frac{114.6}{T} Q \; W(u)$$

s = drawdown in feet
Q = pumping rate in gpm
S = storage coefficient

$$u = \frac{1.56 . r^2 S}{Tt}$$

r = distance from pumping well to observation well
t = time since pumping started

(The relationship between u and W(u) is given in standard tables)

By means of these equations the drawdown at any moment at any distance from a pumped well can be calculated.

1) Test well pumping @ 200 gpm. at test site #1

Drawdown Table - 200 gpm. after one day

Distance from pumping well r feet	r^2	u	W(u)	Drawdown in feet after one day
1	1	6.~~40~~63 $\times 10^{-6}$	11.38	5.52
10	100	6.~~40~~63 $\times 10^{-4}$	6.78	3.30
100	10,000	6.~~40~~63 $\times 10^{-2}$	2.23	1.08
200	40,000	2.65 $\times 10^{-1}$	1.01	0.49
300	90,000	5.95 $\times 10^{-1}$	0.46	0.24
500	250,000	1.65	0.09	0.04
1,000	1,000,000	6.40	-	-

Drawdown Table - 200 gpm. after 2 years

Distance from pumping well r feet	r^2	u	W(u)	Drawdown in feet after two years
1	1	9.~~51~~09 $\times 10^{-9}$	17.89	8.68
10	100	9.~~51~~09 $\times 10^{-7}$	13.29	6.45
100	10,000	9.~~51~~09 $\times 10^{-5}$	8.68	4.22
200	40,000	3.82 $\times 10^{-4}$	7.30	3.55
300	90,000	8.60 $\times 10^{-4}$	6.48	3.25
500	250,000	2.38 $\times 10^{-3}$	5.46	2.65
1,000	1,000,000	9.~~51~~09 $\times 10^{-3}$	4.09	1.99

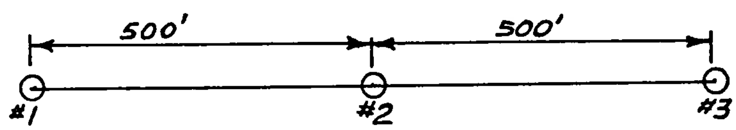
See attached graphical representation.

WELL FIELD DESIGN

Interference Calculations, based on 3 wells spaced in a linear arrangement 500' apart parallel to the Wapiti River - each producing at a measured rate of 200 gallons/min. after oneday and two years.

This is using 15' of water-saturated gravels - 15' was total available drawdown during the test at test site #1.

Let #1 well of test site #1 be the central well (#2) of arrangement.



To be added to calculations - recharge amount of recovery - to be determined

To be subtracted - well loss.

INTERFERENCE TABLE - after one day

Interfering with	Well #1		Well #2		Well #3	
	Distance	Interference	Distance	Interference	Distance	Interferenc
Well #1			500	0.04	1,000	-
Well #2	500	0.04			500	0.04
Well #3	1,000	-	500	0.04		
Total Interference		0.04		0.04		0.04
Own Drawdown		3.48		3.48		3.48
Recharge	?	?	?	?		?
Well Loss	-	--	-	-	-	-
Total Drawdown		3.52 ±		3.56 ±		3.52 ±

INTERFERENCE TABLE - after two years

Interfering with	Well #1		Well #2		Well #3	
	Distance	Interference	Distance	Interference	Distance	Interferen
Well #1			500	2.65	1,000	1.99
Well #2	500	2.65			500	2.65
Well #3	1,000	1.99	500	2.65		
Total Interference		4.64		5.30		4.64
Own Drawdown		6.78		6.78		6.78
Recharge	?	?	?	?	?	?
Well Loss	-	-	-	-	-	-
Total Drawdown		11.42 ±		12.08 ±		11.42

temperature measurements indicate no recharge.

These calculations do not allow for any recharge - this relationship will have to be determined as outlined.

this helps - but the existence of a barrier boundary is also ignored

It can be seen from the above that if a minimum saturated thickness of the gravel of 15 feet is maintained, there should be ample water.

Well loss is also ignored

Well Completion - to reduce well loss

In unconsolidated sands and gravels such as are found in the alluvial terraces along the Wapiti River at the Grovedale Bridge, the proper way to complete a well is to install a well screen opposite the water-saturated portion of the aquifer.

A 6" slot #50 well screen of the Johnson Everdur type should be installed opposite coarse and very coarse gravel. In the case of 15 feet of water-saturated gravels, a 15-foot 6" screen which will provide 1395 square inches of opening - which is several times that of a slotted casing.

The advantages of well screen over slotted well casing are several:

1) In slotted casing the high entrance velocity of the water will deposit part of its mineral content on and around the well - this will severely limit production and will eventually have to be removed by acid treatment, which in turn corrodes the casing. Because of the large open area of the screen the entrance velocity is reduced to such an extent that encrustation is unlikely to occur. If any treatment is necessary, well screens usually have considerably more resistance against this treatment than ordinary water-well casing.
2) The "well loss" with a screen will be 6 to 10 times less than if the well is finished with slotted casing. This will mean a considerable reduction of cost in pumping per day.

Well Loss

The actual drawdown in a pumped well is slightly more than the calculated drawdown due to head loss during flow of water into the well.

This "well loss" is generally the result of poor well construction. In a properly-screened well the well loss can be reduced to 5 to 15 per cent of the calculated drawdown. This loss has to be added to the total drawdown calculations to determine the correct actual drawdown.

Hydrologic Boundaries and Conditions

The pumping test at test site #1 was not carried out long enough to establish clearly the effective recharge of infiltrated water from the river to well.

Several discharge boundaries were noted - which usually show up in the early stages of pumping tests in unconfined aquifers.

Probable permeability boundaries that were noted:

1) effect of cone of influence with intersection of alluvial terrace gravels with bedrock wall to south of pumping test site

2) minor effect of cone influence with intersection of alluvial terrace gravels - with perennial stream (Wapiti).

The pumping test was not carried out long enough in the trial run to establish clearly the boundaries, and it appears a minimum pumping test period of at least 48 hours is needed.

To be determined

1) Relationship between groundwater level in alluvial terraces and fluctuations in Wapiti River level at various times of the year -

At certain times of the year alluvial terraces might be effluent into the river;

At certain times of the year alluvial terraces might be influent.

The maximum and minimum water levels have to be established so that a minimum saturated thickness of the alluvial terrace gravels can be established.

Rate of induced infiltration to be determined

This can be done by:

1) Establishing a water-level recorder, Stevens & Leupold F.M. monthly type, in the pumping well of test site #1. This well was left open for this purpose.

2) Establishing a system of measuring the stream flow of the Wapiti River. Water-level measurements should be made daily.

3) The observation well location should be surveyed in, and its elevation with regard to sea level established. Similarly, stream-flow records should be made from a known elevation.

In this way the water-level recorder measurements and stream flow measurements can be correlated.

The above has to be done before any accurate estimation of the saturated thickness at various times of the year of the alluvial terrace can be made for well design purposes.

See attached folder containing elevations established on the Grovedale Bridge at the Wapiti by the Department of Highways.

To Evaluate Alluvial Terraces

1) During the pumping test - Test Site #1, August 20-21, 1960 - the approximate saturated thickness of the gravels was approximately 15 feet. This thickness can vary because at different times of the year the alluvial terrace (an unconfined aquifer)is

1) hydraulically connected with the Wapiti River;

2) receives groundwater recharge from the steep banks of the Wapiti - i.e. surface run-off, etc., which is captured by the pervious gravels.

3) Piezometric surface of Wapiti formation is effluent towards the river.

4) Resulting piezometric surface is slightly higher than river level at certain times of the year (exact relationship to be established).

1. The Research Council of Alberta established an observation well at test site #1 as part of a program to determine the relationship between stream flow and groundwater recharge or discharge of alluvial terraces along major drainage channels.

2. This test site was drilled at the most accessible site.

To evaluate the terrace fully for eventual water well production for a community such as Grande Prairie the following must be evaluated:

1) the thickness of the alluvial terrace on the south side of the river - see attached sketch for proposed drilling site.

2) the thickness of alluvial terraces on the north side of the river - see sketch for proposed drilling sites.

3) This can be done by test drilling.

From Research Council Test Site #1 the saturated thickness of the gravels was approximately 15 feet on August 20 and 21, 1960.

It has been established from the pump test at Research Council Site #1 that the average transmissibility was 47,100 gallons/ft/day and the resultant average permeability P in gallons/ft^2/day = 3,140.

We have the simple relationship that

$$T = Pm$$

where

T = transmissibility

P = Permeability

m = saturated thickness of aquifer

$\therefore$ doubling the saturated thickness of the aquifer

$$T = 3,140 \times 30$$

$$T = 94,200 \text{ gallons/ft/day}$$

Actually in the case of an unconfined aquifer, doubling the saturated thickness slightly more than doubles the transmissibility.

Maximum production from 15 feet of saturated gravels was 335 gallons/min. if well was 100 per cent efficient.

$\therefore$ maximum production from 30 feet of saturated gravels will be in the order of 1,340 gallons/min. if well was 100 per cent efficient.

This increase in production obtainable from one well by doubling the thickness of the saturated gravels I think fully warrants a thorough test-drilling and pumping test program for the terraces on both sides of the river (as outlined) if any large supply of water is desired.

See attached appendixes for:

1) Pumping test requirements
2) Water quality
3) Test-drilling procedure
4) Logs of test holes

See Fig. 1 - location sketch
Fig. 2 - graphical results of pumping test.

Sgd.

John F. Jones, P. Geol.
Groundwater Geologist,
Dist. #1 - Northern Alberta,
Research Council of Alberta.

October 12, 1960.

Appendix I

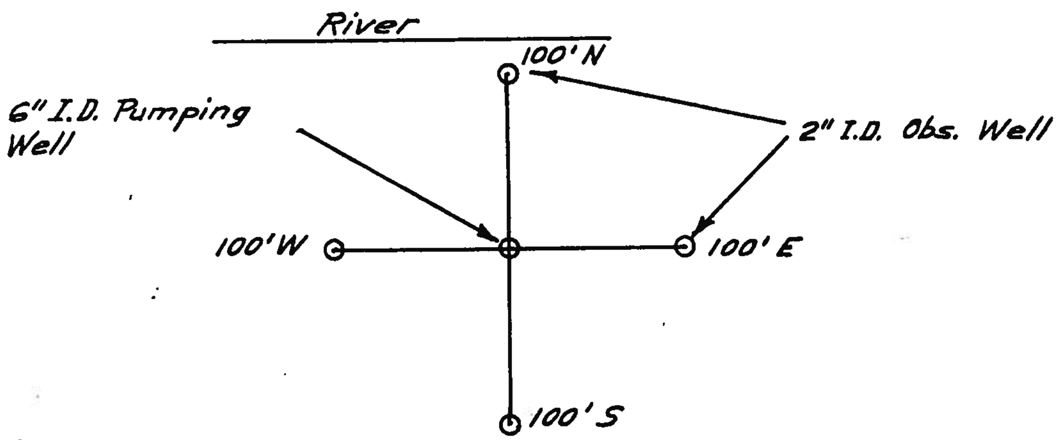
Test Site - Pump testing

The minimum requirements to obtain the necessary information for well design in alluvial terrace gravels appear to be:

One pumping well and
four observation wells.

See sketch for distance.

No observation well should be closer to the pumping well than 1.5 m. to 2.0 m. where m = saturated thickness of aquifer.



Length of Test

1) Minimum of 48 hours a well if possible.

2) Rate - pumped at least 200 gpm. at a constant rate.

3) Temperature readings of water taken throughout test.

4) Water samples taken regularly throughout test.

5) Static levels of wells determined prior to test.

6) Pumping well should have water-level measured during test, i.e. air line gauge (both drawdown and recovery)

7) Observation wells should have water-level measurements made - both drawdown and recovery.

8) Discharge of pumping water into the river so that none leaks back into the aquifer; if it does it will give erroneous drawdown and recovery readings.

9) Observation well and pumping well should be surveyed in with a known elevation

Properly carried out the above should give all the necessary information regarding proper well field design and completion.

Appendix II

Test Hole Logs

Wapiti River - Grovedale Bridge - Site #1

Test Hole #1 - Pumping Well (Recorder installed)

0 - 8.5	Silt, sand, minor clay
8.5 - 26.0	Gravel, coarse, minor sand 15' sat'd
26.0 - 29.0	Gravel, coarse to medium
29.0 - 36.0	Shale, grey, Wapiti Formation (Bedrock)

Test Hole #2 - 40' East obs. well

0 - 13	Silt, sand and clay
13 - 18	Gravel (coarse) boulders
18 - 24	Gravel (coarse)
24 - 29.5	Gravel
29.5 - 30.0	Shale, grey, Wapiti Formation

Test Hole #3 - 100' West, obs. well

0 - 12.5	Silt and clay
12.5 - 28.0	Gravel (coarse)
28.0 - 35.0	Shale, grey, Wapiti Formation

Test Hole #4 - 100' south obs. well

0 - 13.0	Silt and clay
13.0 to 28.5	Gravel
28.5 - 30.0	Shale, grey, Wapiti Formation

Test Drilling

Test drilling was carried out using a Mayhew 1000 rotary drill. It was found to be most satisfactory drilling in the gravels if certain procedures were followed:

1) When commencing drilling, the drilling fluid which is just normally clear water had drilling mud added to it, 1 or 2 bags of Polygel or Supercol or some similar mud. To thicken the mud a small amount of lime was normally added.

2) Drilling the pumping well 6 7/8" roller rock bits were used. Drilling was commenced with the drilling fluid as above. The drilling rig pumps circulating the drilling fluid were hardly used at all as the mud column was used to hold back the coarse gravel as it was drilled through. When the gravels were drilled through into the bedrock the drill stem was pulled out still not disturbing mud in the hole and 4 1/2" OD water-well casing, slotted, run in. Then and only then after the casing was set the heavy thick drilling mud was bailed and thoroughly flushed out.

If larger diameter wells are desired, larger rock bits should be used and same procedure followed.

The time to drill was 2 days through 25 of gravel in this way.

Observation Wells

For water level measurement to observe drawdown and recovery measurements for test purposes to save time 4 3/4" rock bits were used to drill a 4 3/4" hole. Drilling procedure was the same for the pumping well except with the smaller hole the drilling was speeded up immensely. 2" I.D. black pipe was used for the observation wells. The pipes were slotted the full length of the saturated portion of the aquifer. After dropping the pipe in the holes the mud was bailed and flushed out to make sure the observation wells were efficient.

Two observation wells drilling through 25 feet of coarse gravel were drilled each day if the above procedure was followed.

Water Quality and Temperature

Water samples were taken at the beginning and end of the pumping test - River temperature also taken.

1) August 17, 1960 - Water from pumping well at 4:05 p.m.

   Temperature = 4.5°C or 40.1°F

   River water temperature = 17.5°C or 63.5°F at 4:20 p.m. 10' from river bank

2) August 20 - Water sample - pumping well at 10:15 a.m. Temperature 4.5°C or 40.1°F.

3) August 21 - Water sample, pumping well at 11:15 a.m. Temperature 4.5°C or 40.1°F

Comparison of Water Quality in Parts per Million (Provincial Analysis)

Nature of Constituents	Wapiti River April 7/59	Well Samples #1 Aug. 17/60	#2 Aug. 20/60	#3 Aug. 21/60
Total Solids	162	896	844	876
Ignition Loss	34	208	232	214
Hardness	85	390	380	405
Sulphates	38	63	100	129
Chlorides	nil	2	3	3
Alkalinity	95	630	585	595
Nature of Alkalinity	Bicarb of Na, Ca & Mg			
Nitrates	trace	trace*	nil	nil
Nitrates	0.5	2.0	nil	nil
Iron	0.7	6.0	4.5	4.5
Soda - grains/gal		24.8	15.2	12.10

*well just developed.

When percolating through the gravels the river water picks up calcium and magnesian bicarbonates which results in a higher alkalinity of the infiltrated water. Chlorides are also higher.

When the water is made to move faster and the pumping is carried on continuously these high amounts are believed to decrease rapidly and tend to approach the average chemical quality of the river.

Temperature of infiltrated water

The temperature of the river water and well water were quite different as of August 17, 1960.

The well water was 40.1°F
The river water was 63.5°F

The usual temperature range of groundwater will be far less extreme than that of the river water which will probably range from 32°F in the winter to 68 or 70°F in the summer.

The expected temperature of the groundwater should be in the range from 36°F to approximately 50°F.

This can be accurately determined by pump testing and keeping a close check on the river water throughout the year.

The well water will probably be coolest during spring and early summer and warmer during the fall and early winter.

Kazman (1948)* pointed out that the relationship of the temperature of surface water and infiltrated water is quite complex and listed the following important points:

1) Mixing of groundwater with infiltrated water
2) Admixture of river water of different temperature, while enroute to the well
3) The heat storage of the aquifer and underlying rocks
4) The conduction of heat upward and laterally within the aquifer due to temperature gradients.

As a result of these processes the aquifer produces water that is cooler than the warmest river water but warmer than the river lows.

Temperature and Viscosity of Water

As a result of the temperature fluctuation the coefficient of viscosity of water will decrease from a summer high to a winter low and will result in a longer flux of water towards the well in winter months - which phenomenon may cause the calculated drawdown in the wells to be slightly less in the order of 0.5'.

* R.G. Kazman (1948): River infiltration as a source of groundwater supply; Trans. Am. Soc. Civil Eng., Vol. 113, p. 404 - 424.

SUMMARY OF MAIN POINTS TO EVALUATE ALLUVIAL TERRACES - WAPITI RIVER, SOUTH OF GRANDE PRAIRIE, ALBERTA - TO OBTAIN A LARGE SUPPLY OF GROUNDWATER

1. Establish a water-level recorder to measure the fluctuations in the level of the watertable in the alluvial terrace at the Wapiti River - Grovedale Bridge, and determine its relation to variation in stream flow of the Wapiti River.

2. Establish a system of measurements (daily) of stream flow of the Wapiti River, at the Grovedale Bridge.

3. Collect water samples and take temperature readings of the Wapiti River on a monthly basis for a minimum period of one year.

4. Test drill the alluvial terraces to determine the maximum saturated thickness of the gravels.

5. Pump test the alluvial terrace gravels as outlined. Take water samples and temperature readings of water from pumping well.

6. The above-mentioned carried out will give the necessary information to design a well or well field to supply a large amount of groundwater.

7. Based on present information and saturated thickness of the alluvial terrace gravels as of August 20 and 21, 1960, determined at test site #1, 3 wells, 500 feet apart pumping at 200 gpm. will produce 864,000 gallons per day. This can be increased by adding additional wells.

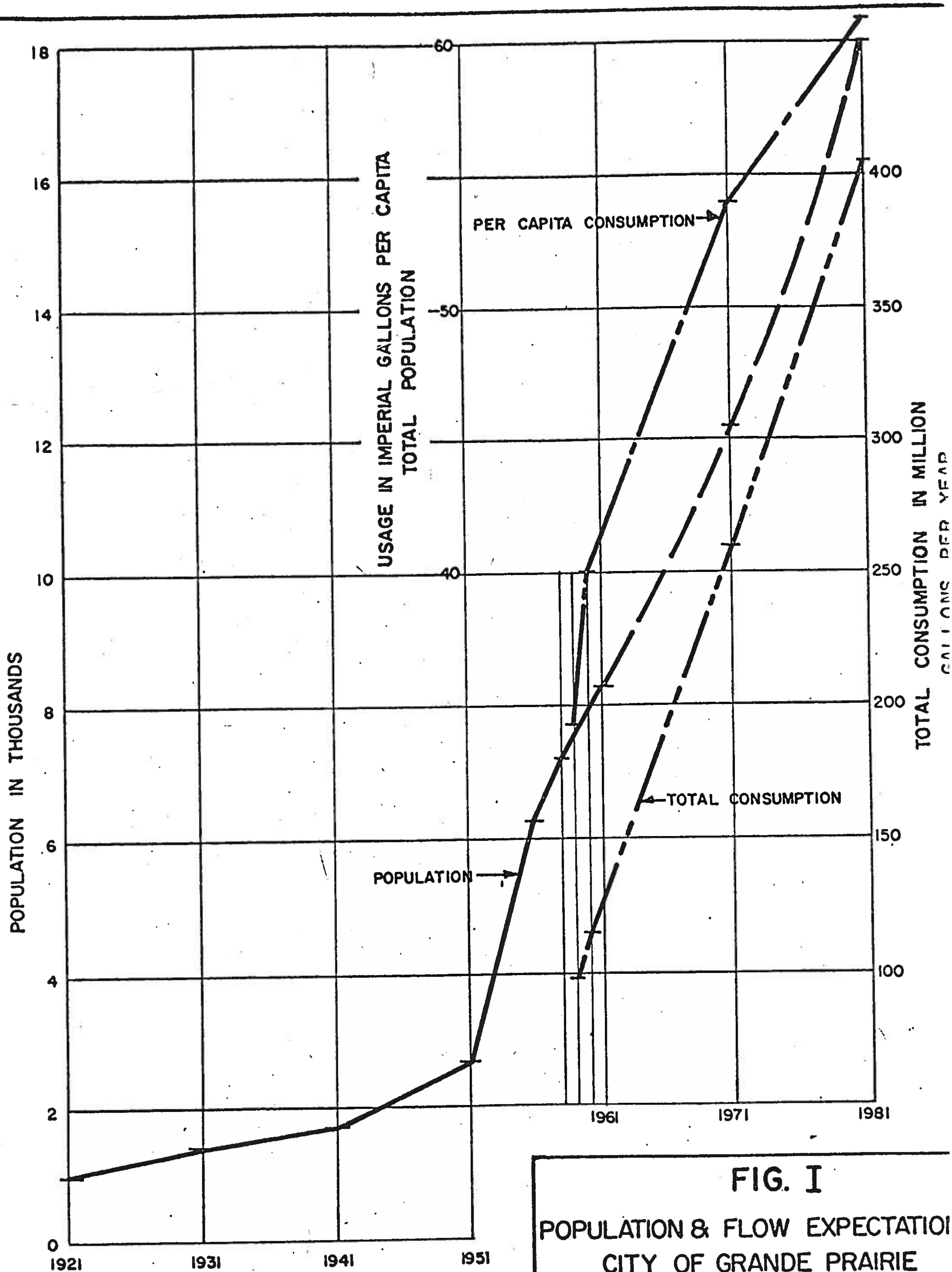


FIG. I

POPULATION & FLOW EXPECTATIO
CITY OF GRANDE PRAIRIE
WATER SUPPLY REPORT
STANLEY, GRIMBLE, ROBLIN LTD.
224-1

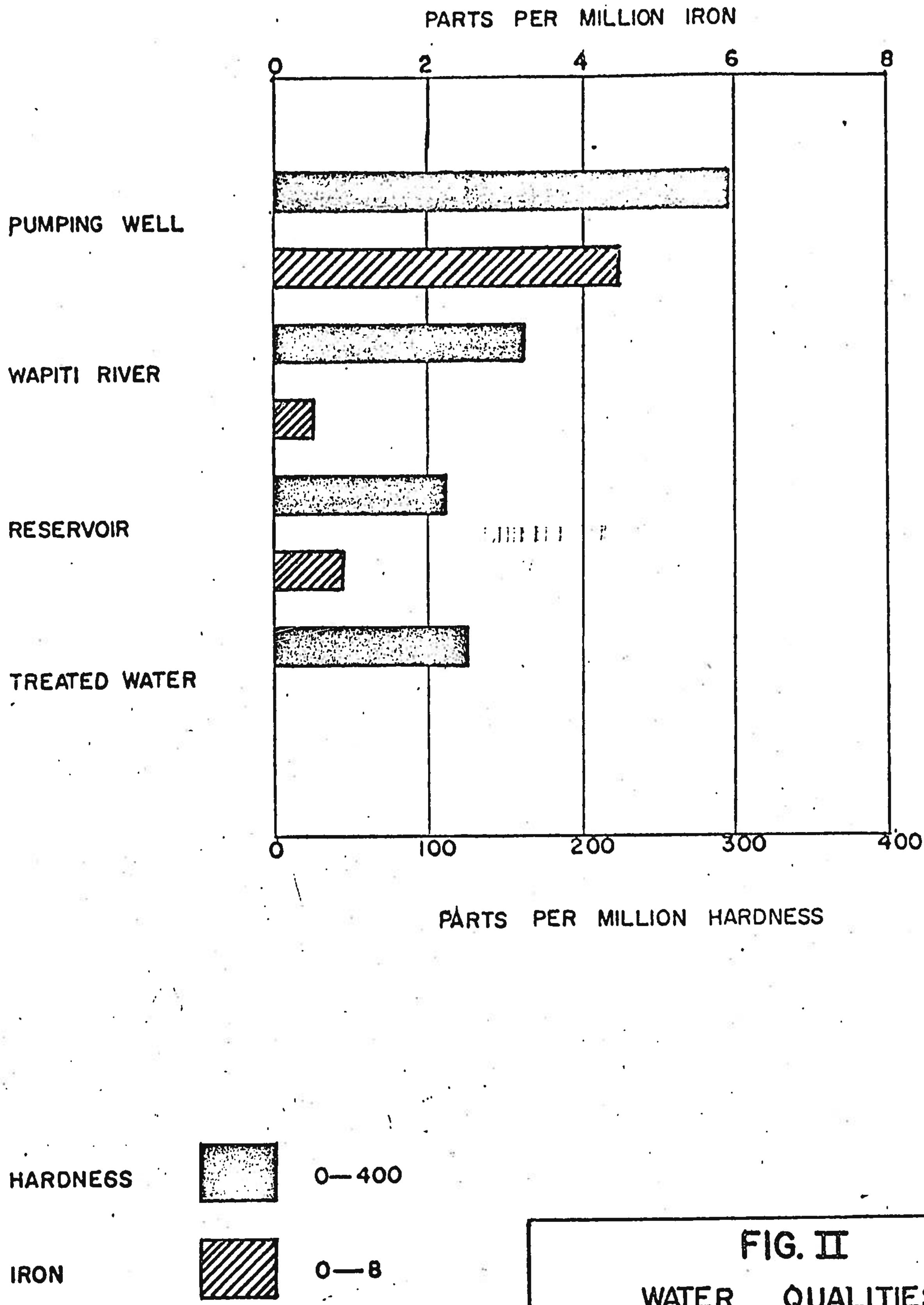


FIG. II

WATER QUALITIES
CITY OF GRANDE PRAIRIE
WATER SUPPLY REPORT
STANLEY, GRIMBLE, ROBLIN LTD.
224-1-2

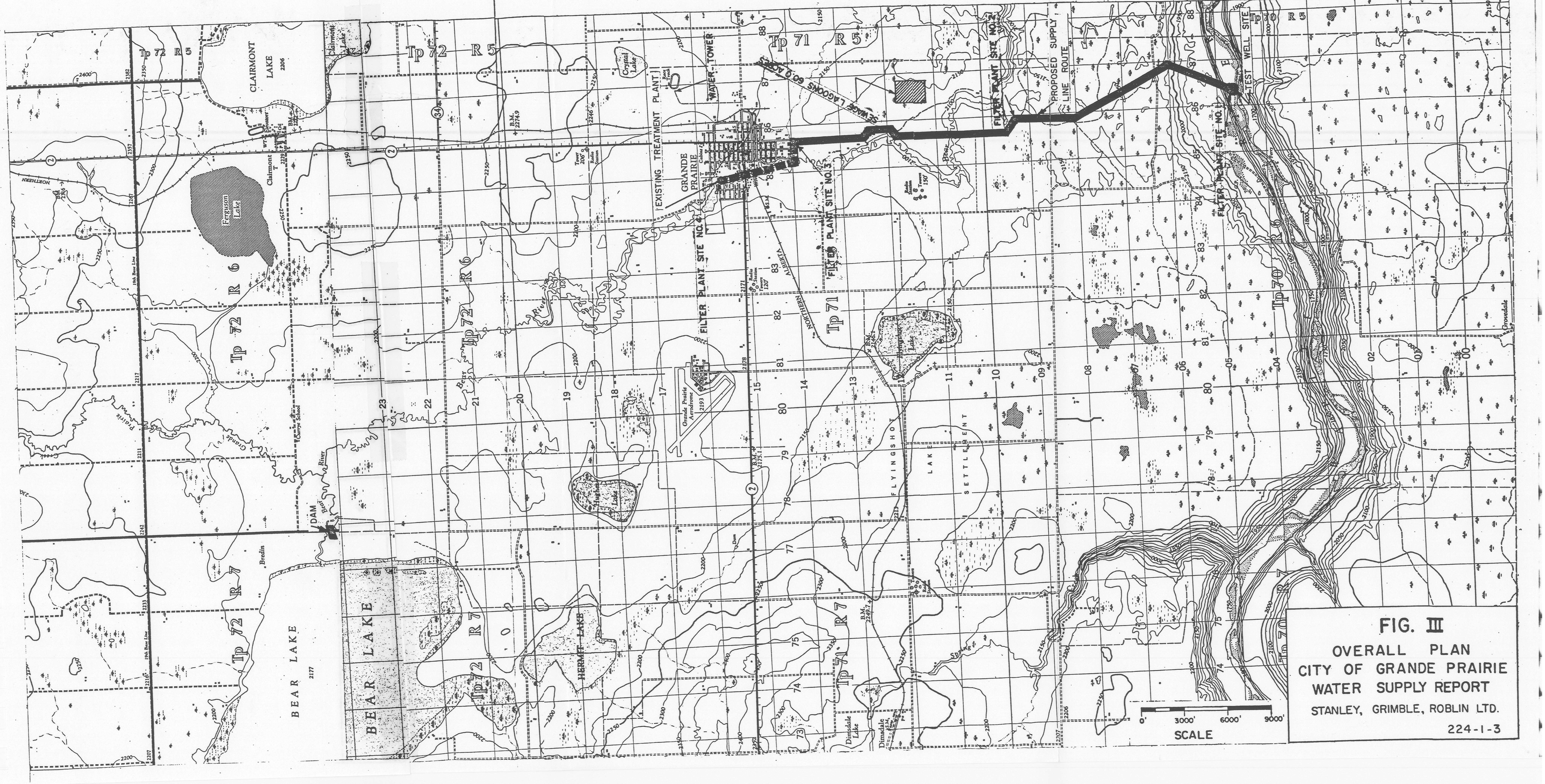


FIG. III
OVERALL PLAN
CITY OF GRANDE PRAIRIE
WATER SUPPLY REPORT
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224-1-3

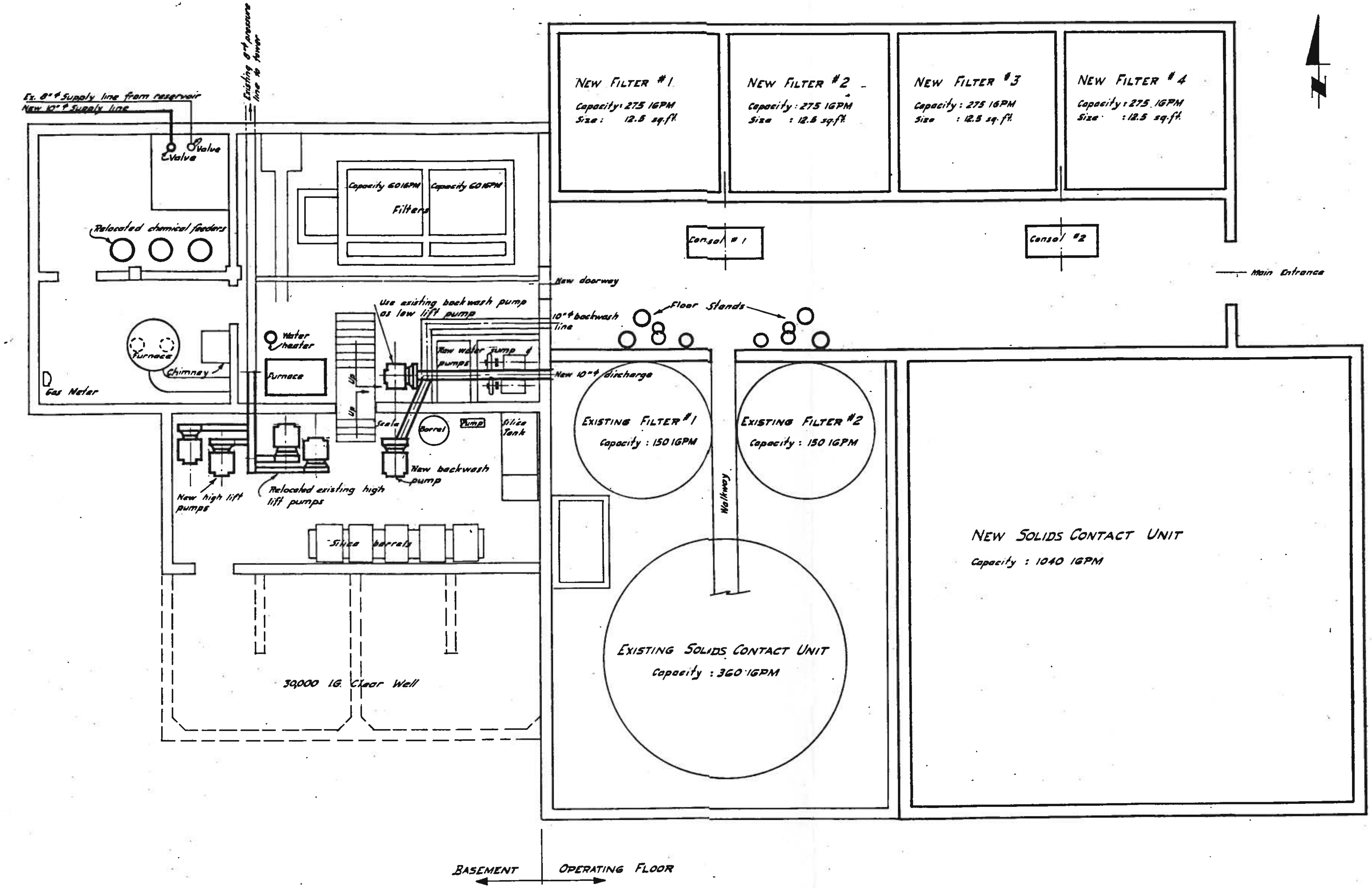

FIG. IV

SKETCH PLAN OF PROPOSED PLANT EXPANSION
CITY OF GRANDE PRAIRIE
WATER SUPPLY REPORT

STANLEY, GRIMBLE, ROBLIN LTD.

224-1-4

Herald Tribune, Alta.
Grande Prairie
February 12, 1960

229-1

Province May Aid Tests of Wapiti

761

A series of test drillings and pumping will likely get underway on the banks of the Wapiti River, south of Grande Prairie, in May or June to determine the practicability of tapping the river for the city's water supply, it was announced today by Alderman Fred Noble.

Tests for the water supply would be carried out by the provincial research council under a scheme, due to go before the legislature shortly, which would allow smaller centres like Grande Prairie to apply for and obtain a drilling and pumping report on ground water potential in the district.

The proposal has to be presented to city council, also for approval.

Under the scheme the Alberta Research Council would supply all the engineers, geologists and other trained personnel to carry out the tests and would not charge for any supervisory work.

If the tests should prove that there is insufficient or unsuitable water, then the Research Council would only charge the city 20 per cent of their out-of-pocket expenses.

On the other hand, however, if the tests are successful and an answer to the city's water supply is found, then the city would be required to pay the full cost of the tests, less the supervisory fees. Generally speaking, supervision adds up to in the region of 35 per cent of the costs of such a project.

Alderman Fred Noble interviewed Dr. Gravenor of the Alberta Research Council during a recent visit to Edmonton and has brought back the Wapiti testing proposals for presentation before city council.

Problem of an alternative water supply for the city has been facing city council for some time now. The problem was dramatically underlined last spring when water became unpalatable, had an unpleasant odor and came out of faucets a dirty looking brown color.

Algae in the reservoir were blamed for the water's unpleasant characteristics which although making the water unpalatable did not make it a danger to public health.

At that time it was decided that the possibilities of the Wapiti as an alternate water supply should be investigated.

It has been estimated that an engineering test of the Wapiti's water would cost at least $10,000. While a test as complete as that envisioned by the Alberta Research Council would cost in the region of $20,000—if carried out by a commercial engineering concern.

The cost of the tests under the Research Council are expected to cost the city very much less.

If the provincial government gives the go ahead to the Research Council, and city council approves the expenditure on the Wapiti tests, it is expected that engineers and geologists will start work on the river's banks in May or June.

Two possible sites have been chosen for the tests. One is located adjacent to the Grovedale bridge, while the other is about one mile upstream.

2291 Feb 61 / 60

City May Secure Aid In Search For Water

GRANDE PRAIRIE — If the city council approves the expenditure, the Alberta Research Council will conduct a series of drilling tests and pumping on the banks of the Wapiti River by early summer, a council spokesman announced. The tests will be conducted in an effort to determine practicability of tapping the Wapiti as source of water supply for the city and are part of a plan which allows smaller centres like Grande Prairie to apply for and obtain a drilling and pumping reports on ground water potential in the district. Alberta Research Council will supply engineers, geologists and other trained personnel and will not charge for supervision. If the tests should prove an insufficient supply or unsuitable water, then the Research Council will charge the city only 20 per cent of its out-of-pocket expenses.

On the other hand, if the tests are successful the city will be required to pay the full cost, less supervisory fees. Generally speaking, supervision comprises about 35 per cent of the costs.

The problem of an alternative water supply came to the fore last spring when water became unpalatable, had an unpleasant odor and came out of faucets a dirty brown color.

Algae in the reservoir were blamed for the water's characteristics which, although making it unpalatable, did not make it a danger to health.

At that time it was decided that the possibilities of the Wapiti as an alternate water supply should be investigated.

It was estimated that an engineering test of the Wapiti's water would cost at least $10,000, while a test as complete as that envisioned by the Alberta Research Council would cost about $20,000, if carried out by a commercial engineering concern. Tests by the Research Council are expected to cost the city very much less.

Sites chosen for the tests are located adjacent to the Grovedale bridge south of Grande Prairie and about one mile upstream.

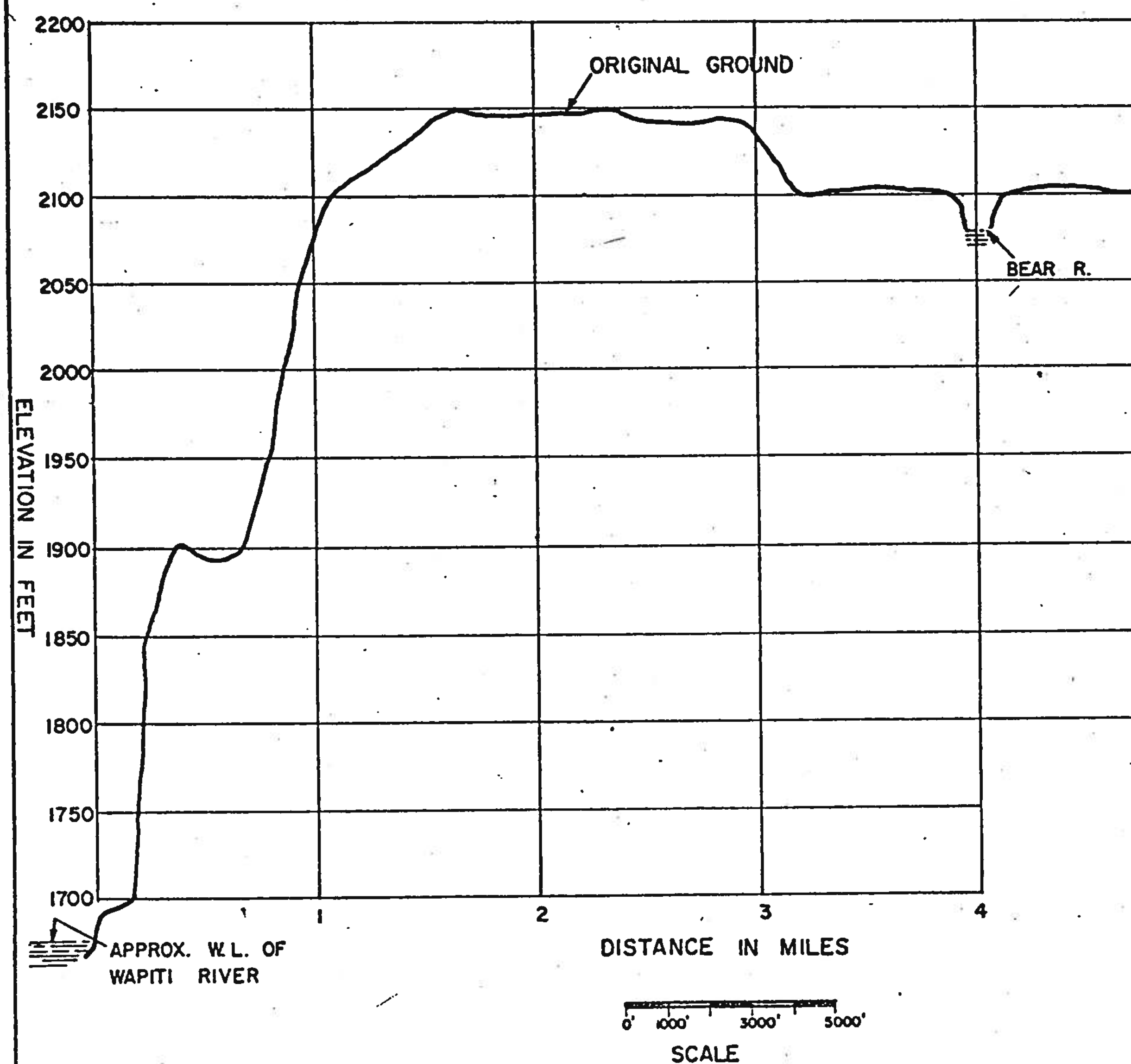

FIG. V

SUPPLY LINE

CITY OF GRANDE PRAIRIE

WATER SUPPLY REPORT

STANLEY, GRIMBLE, ROBLIN LTD.

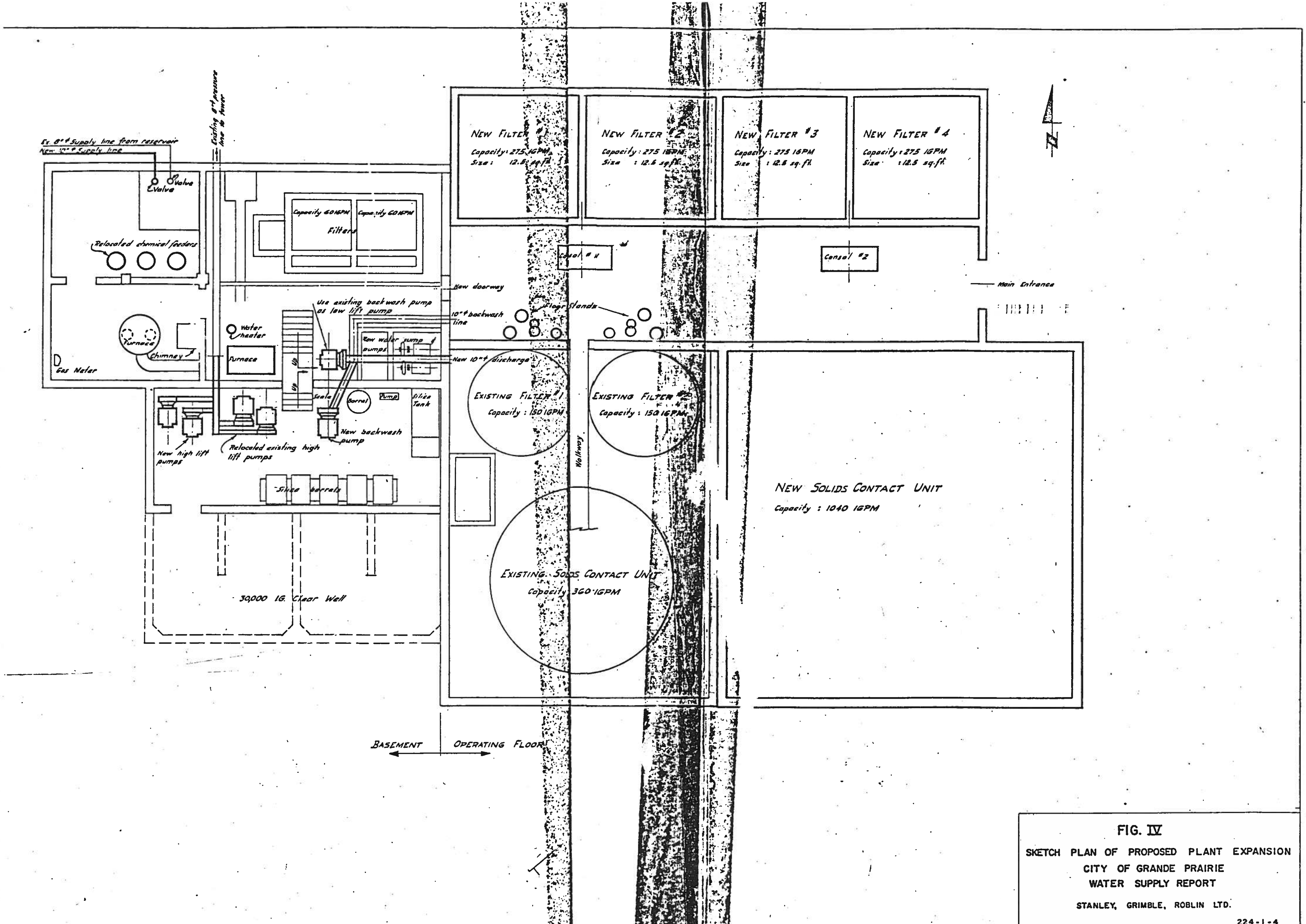

FIG. IV

SKETCH PLAN OF PROPOSED PLANT EXPANSION
CITY OF GRANDE PRAIRIE
WATER SUPPLY REPORT

STANLEY, GRIMBLE, ROBLIN LTD.

224-1-4

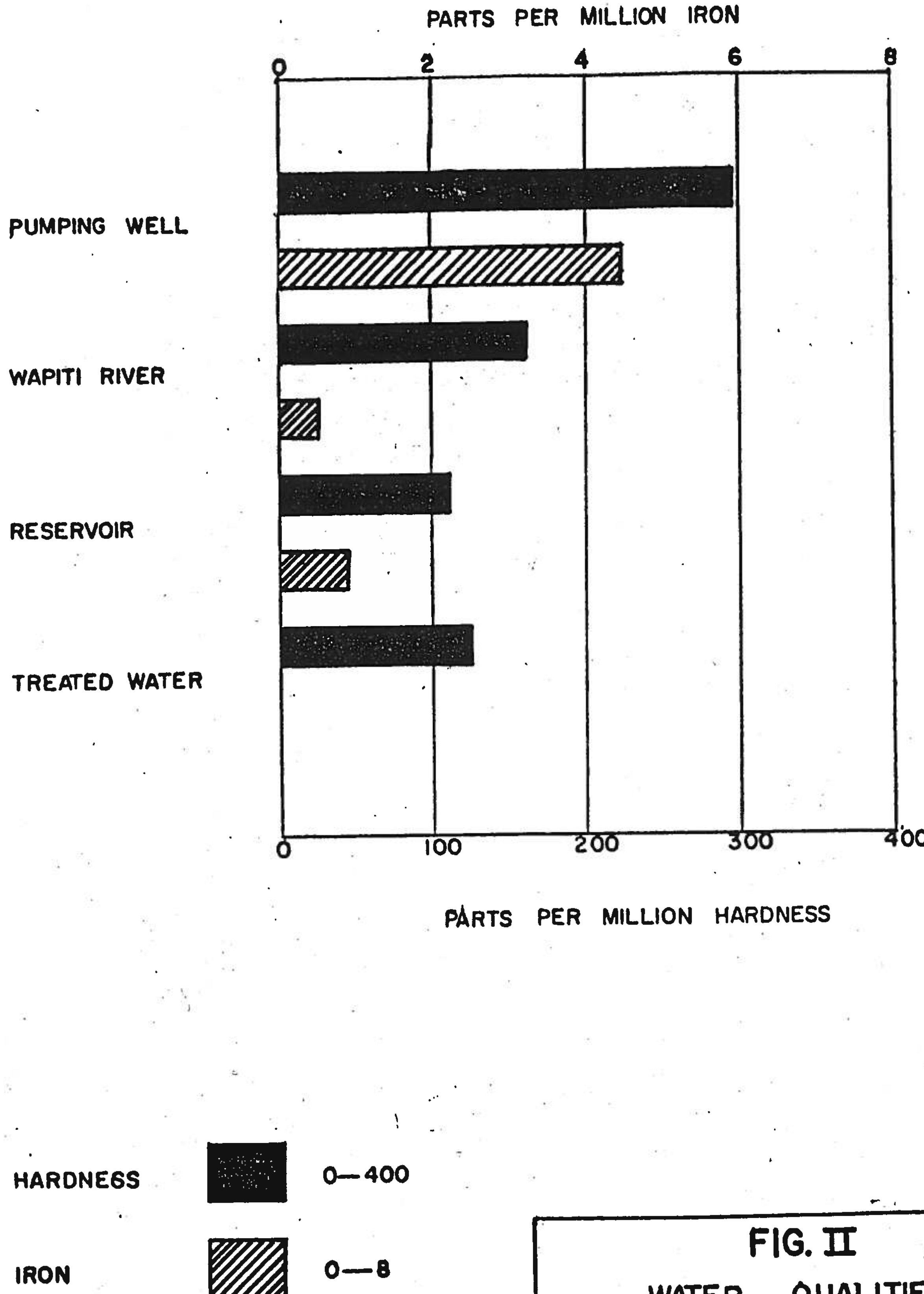

FIG. II

WATER QUALITIES
CITY OF GRANDE PRAIRIE
WATER SUPPLY REPORT
STANLEY, GRIMBLE, ROBLIN LTD.
224-1-2

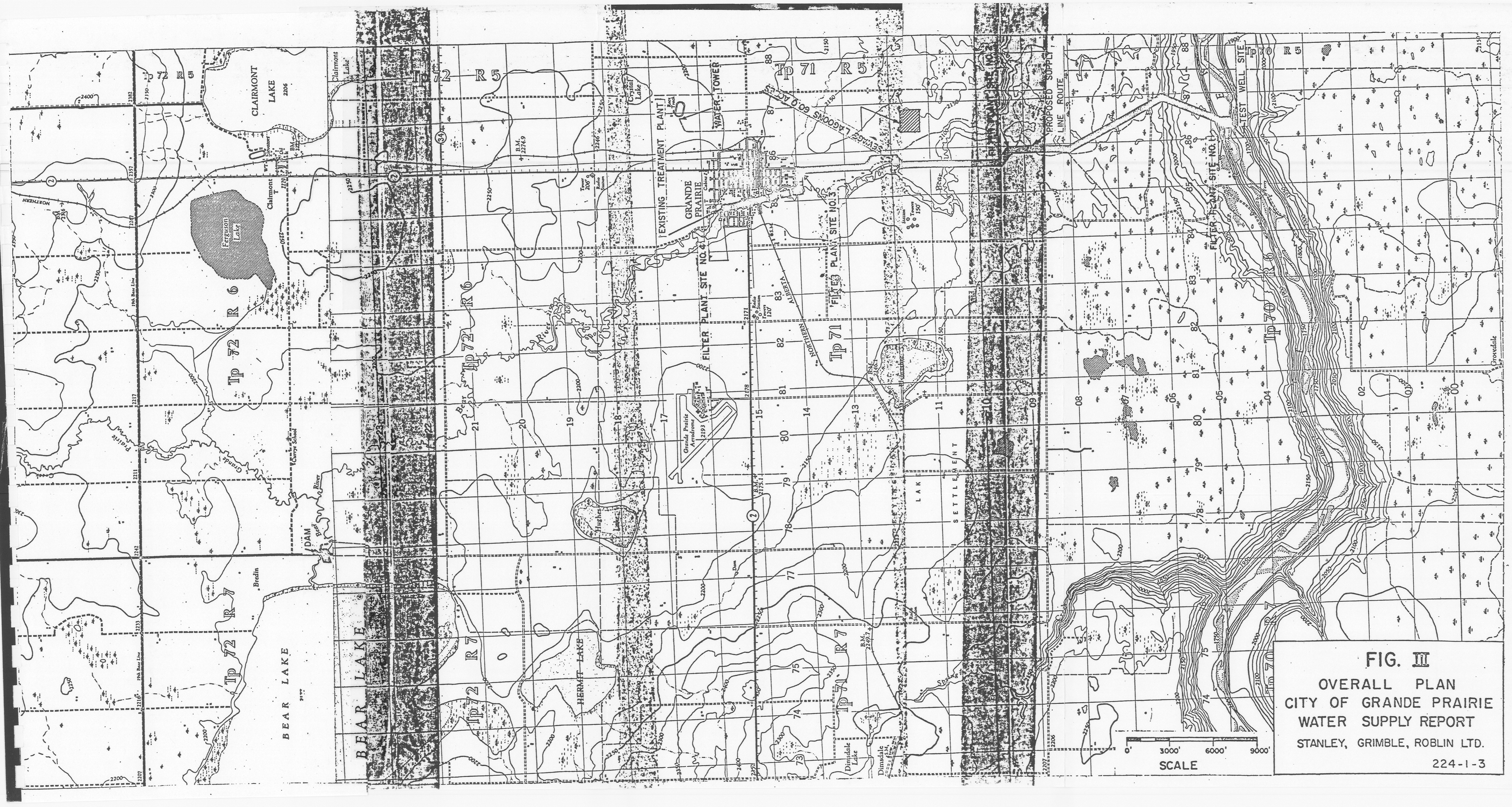

FIG. III
OVERALL PLAN
CITY OF GRANDE PRAIRIE
WATER SUPPLY REPORT
STANLEY, GRIMBLE, ROBLIN LTD.
224-1-3

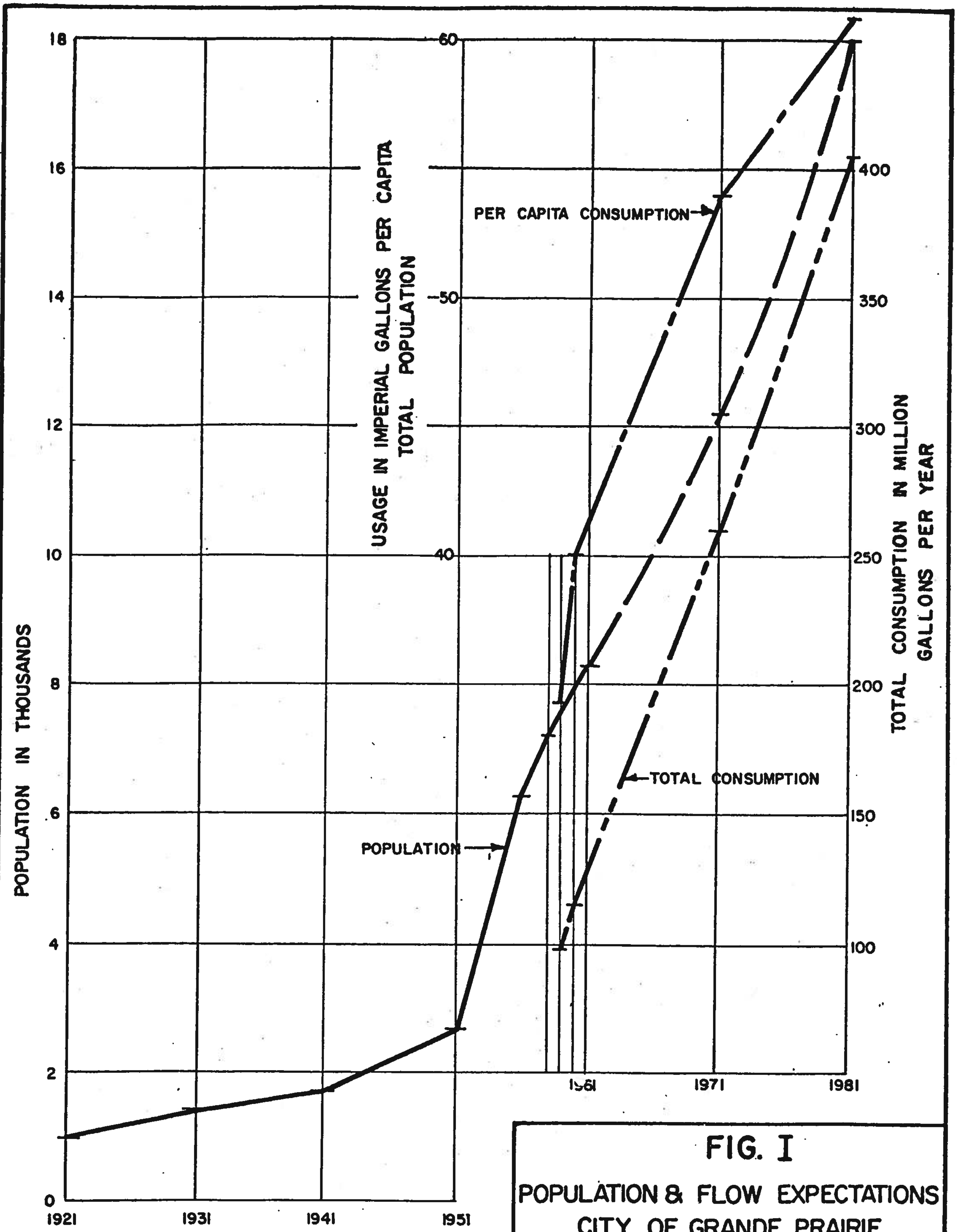

FIG. I

POPULATION & FLOW EXPECTATIONS
CITY OF GRANDE PRAIRIE
WATER SUPPLY REPORT

STANLEY, GRIMBLE, ROBLIN LTD.